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TITLE OF THE INVENTION (280 characters max)

WIRELESS COMMUNICATION METHODS, SYSTEMS, AND SIGNAL STRUCTURES

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Respectfully submitted,

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PROVISIONAL APPLICATION COVER SHEET
Additional Page

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WIRELESS COMMUNICATION METHODS, SYSTEMS, AND SIGNAL STRUCTURES

Field of the Invention

This invention relates generally to communications and in particular to wireless communications.

Background

Current communication techniques and associated air interfaces for wireless communication networks achieve limited capacity, access performance, and throughput.

Summary

Embodiments of the invention provide communication signal structures, and communication signal methods and systems, which enhance the performance of wireless communication systems.

Other aspects and features of embodiments of the present invention will become apparent to those ordinarily skilled in the art upon review of the following description of the specific embodiments of the invention.

Brief Description of the Drawings

Examples of embodiments of the invention will now be described in greater detail with reference to the accompanying diagrams, in which:

Fig. 1 is a block diagram of a frame and slot structure;

Fig. 2 is a block diagram of frame, slot and sub-channel structures with a flexible TDD slot allocation and tail symbol;

Fig. 3 is a block diagram showing an example user to sub-channel and antenna mapping scheme;

Fig. 4 is a block diagram of a MIMO-OFDMA tile for UL diversity sub-channel;

Fig. 5 is a block diagram of an example MIMO-OFDM tile for UL AMC sub-channel;

Fig. 6 is a block diagram of an example Virtual MIMO UL structure for the diversity sub-channel (tile);

Fig. 7 is a block diagram of an example virtual MIMO UL structure for the AMC sub-channel (tile);

Fig. 8 is a block diagram of a closed loop 4x1 MISO system for the AMC sub-channel;

Fig. 9 is a block diagram of a transmit system for 2x2, 2x4 MISO/MIMO transmission;

Fig. 10 is a block diagram of a 4x2 Sub-MIMO BLAST system;

Fig. 11 is a block diagram of a multi-user MIMO system for the AMC sub-channel;

Fig. 12 is a time domain representation of an example preamble structure;

Fig. 13 illustrates an example preamble structure;

Fig. 14 shows an example down link scattered pilot structure;

Fig. 15 illustrates an example basic scattered pilot pattern;

Fig. 16 shows an example space time block code encoded pilot structure;

Fig. 17 illustrates an example scattered pilot power assignment scheme;

Fig. 18 shows an example of variable rate diversity sub-channel construction;

Fig. 19 shows a dyadic tree structure of diversity sub-channel;

Fig. 20 depicts construction of a product code $P=C_1\otimes C_2$;

Fig. 21 is a block diagram of an example LDPC encoder;

Fig. 22 shows an example non-uniform repetition assignment for an LDPC encoder; and

Fig. 23 is an example PRBS generator.

Detailed Description of Preferred Embodiments

In accordance with an aspect of the invention, a basic Multiple Input Multiple Output - Orthogonal Frequency Division Multiple Access (MIMO-OFDMA) air interface is proposed, for IEEE802.16e for instance, to enable the joint exploitation of the spatial time frequency and multi-user-diversity dimensions to achieve very high capacity broadband wireless access for both nomadic and mobile deployments. OFDMA transmission may be used for both down-link and up-link to increase the capacity and quality of the access performance. MIMO transmission may be used to increase the network and user throughput, and multi-beam forming

transmission may be used to increase aggregated network capacity.

In one embodiment, an air interface is designed to allow multiple mode adaptive BS scheduling approach to achieve enhanced performance for various deployment scenarios and Quality of Service (QoS) requirements. The modes may include:

1. Time Division Multiplexing (TDM) to allow IEEE802.16d and IEEE802.16e coexist and provide backward compatibility;

2. TDM/Frequency Division Multiplexing (FDM) to allow MIMO/MISO/SIMO/SISO terminals to coexist;

3. TDM/FDM/MIMO fractional time/frequency reuse sub-channels;

4. TDM/FDM/MIMO Adaptive Modulation and Coding (AMC) sub-channel mapping, diversity sub-channel mapping;

5. TDM/FDM/MIMO adaptation of modulation and Forward Error Correction (FEC) coding with fast antenna sub-MIMO selection;

6. TDM/FDM/MIMO joint adaptation of space time coding modulation and FEC coding;

7. Closed loop MIMO based transmission for fixed and nomadic users; and

8. Open loop MIMO based transmission for high mobility, common channels and multi-cast channels.

One proposed framework supports scalable OFDMA for a wide range of channel bandwidths and it also supports a variety of the antennas/transceiver chains configuration at

both a network element or base site (BS) and subscriber site (SS) ends. At a BS, multi-beam configuration may be further concatenated with MIMO-OFDMA to scale aggregated network capacity. In this case, the MIMO-OFDMA serves as a throughput multiplier to scale the per-beam or per-user throughput, and multi-beam-based higher sectorization effectively serves as a capability multiplier to scale the network capacity and number of active users supported. In addition, a multi-beam MIMO antenna configuration provides an effective tradeoff and enhanced performance of macro-cell based mobility applications.

In a preferred embodiment, a system is designed for macro cellular networks with frequency reuse one, and TDD duplexing is used for flexible spectrum allocation. In addition to basic IEEE802.16d/e system features, a proposed MIMO-OFDMA profile enhancement can be summarized below in Table 1.

QoS	Guaranteed resource allocation with delay bound		No dedicated resource allocation and delay bound
Service	Real time	Non real-time	Best-effort
	Audio/video streaming, interactive game	FTP, multimedia mail, chatting, e-commerce	Web browsing, e-mail
Fixed/	Packet PARC	Packet PARC	Packet PARC (AMC)

Nomadic	(AMC) STTD (DSB)	(AMC) STTD (DSB)	
Mobility	Packet BLAST (DSB) STTD (DSB)	Packet BLAST (DSB) STTD (DSB)	Packet BLAST (DSB)

Table 1

Some illustrative example networking capabilities and resources are: (1) Sub-Channels, namely AMC sub-channel (ASB) and Diversity sub-channels (DSB), (2) MIMO modes, namely the packet BLAST, packet Per Antenna Rate Control (PARC) and Space Time Transmit Diversity (STTD), (3) Coding and modulation, and (4) multi-beam. The SS performs cell/beam selection to access the network and adaptively to perform joint optimization of the air-interface configuration to achieve best performance for each service requirement and user experience.

Embodiments of the invention may include one or more of the following components:

1. Down link adaptive MIMO
2. Up link STTD and virtual MIMO
3. MIMO H-ARQ
4. MISO/MIMO down link configuration and support
5. MIMO preamble and scattered pilots
6. Sub-FFT based AMC and diversity sub-channels
7. MIMO control channel

8. Additional LDPC coding and differential modulations

9. Soft handoff and macro diversity

10. Multi-beam MIMO support

11. Network radio resource planning for MIMO-multi-beam

12. TDD frame/slot structure

According to an embodiment of the invention, a frame structure enables MIMO transmission based on the IEEE802.16e OFDMA physical layer (PHY) and medium access control (MAC) baseline. MIMO-OFDMA can be integrated into scalable OFDMA technology. An adaptive air-interface framework proposed herein allows optimization of radio capacity and network throughput for diverse deployment environments. Examples of potential air-interface enhancement include:

Spectral efficiency enhancement on the order of 40Bits/Sec/Hz/Carrier/Site

Mobility support up to 120km/h vehicular speed

Coverage up to 20Mbps at 99% tile

Battery efficient portable device support.

Table 2 compares several OFDM technologies including MIMO-OFDMA. In Table 2, B = channel bandwidth.

	MIMO-OFDMA		S-OFDMA		256-OFDM	
	DL	UL	DL	UL	DL	UL
Spectral Efficiency	12	6	0.6	0.5	0.3	0.3

(Bit/Sec/Hz/Carrier/Site)						
Aggregated Network Throughput *(Mbps/Carrier/Site)*	12*B	6*B	0.6*B	0.5*B	0.3*B	0.3*B
Coverage *(Mbps/Carrier/Site)*	B @ *99% tile*	B @ *99% tile*	0.08*B @ *67% tile*	0.08*B @ *67% tile*	N/A	N/A

Table 2

A TDD frame structure according to an embodiment of the invention may be designed to meet several requirements: (1) short frame slot length for fast system access, and dynamic sub-channel allocation, fast channel quality indicator (CQI) based adaptive coding and modulation, fast physical layer hybrid Automatic Repeat Request (ARQ) and fast MAC state transition; (2) TDD network interference management and control, including the SS-to-SS and BS-to-BS interference, through network synchronous DL/UL switching point, (3) flexible DL/UL allocation ratio to allow efficient management of variable DL/UL traffic symmetry ratio and adaptation to fixed or mobile deployments.

A proposed hybrid TDD frame structure includes the network planned fixed DL/UL switching point and cell/beam specific flexible DL/UL switching point. The fixed DL/UL switching point ensures the minimum level of TDD specific interference. TDD specific interference caused by the

flexible DL/UL switching point can be mitigated by the BS scheduler and to allow each cell/beam to adjust the DL/UL traffic symmetry ratio. In addition, a tail symbol concept described below allows minimization of the transmit/receive gap an receive/transmit gap (TTG/RTG) overhead caused by the flexible assignment of the DL/UL switching point.

Fig. 1 is a block diagram of a frame and slot structure. In the illustrative example frame of Fig. 1, to which the invention is in no way limited, the TDD frame duration is 10 ms, one TDD frame includes 5 2ms TDD slots, and each TDD slot includes 9 OFDM pairs and one tail symbol. The tail symbol serves as TTG and RTG if a switch happens during the slot, or it can be used as regular traffic channel or preamble. Each OFDM pair consists of two OFDM symbols.

For each TDD frame, the TTG and RTG are inserted between DL burst and UL burst to allow BS transceiver to turn around. The TTG and RTG allow TDD slot based DL/UL switching. The duration of TTG and RTG depends on the minimum switch time and the cell size, the flexibility of the traffic asymmetry improves system efficiency and can be used for dynamic resource allocations depending on cell/beam traffic symmetry ratio. Switching may not assign every TDD slot especially for fixed and nomadic deployment. As the overhead reserved for TTG/RTG is wasted if no DL/UL switching is allocated in a specific slot boundary, the tail symbol is introduced. The tail symbol is a single OFDM symbol, and it is used as regular traffic OFDM symbol or combined with another tail symbol in adjacent slot to generate an OFDM pair. It can be split into two parts, one serves as TTG and the other serves as RTG when DL/UL switch

enabled. The tail symbol also allows reduction in the overhead of narrow band scalable OFDMA.

A 20MHz channel bandwidth and 2048-FFT may be designed as base modes for a scalable OFDMA system parameter set, one illustrative example of which is Table 3.

Parameter	Value
IFFT/FFT Block	2048
Sampling Rate	22.5 MHz (=8/7*20*63/64, 8/7*20 corresponding to IEEE802.16a)
No. of Prefix Samples	320 (328 for Tail Symbol)
Guard Time	14.2222 μs (14.5777 for Tail Symbol)
No. of Samples per Symbol	2368 (2376 for Tail Symbol)
Useful Symbol Duration	91.0222μs
Total OFDM Symbol Duration	105.2444 μs (105.6 μs for Tail Symbol)
Sub-carrier Separation	10.9863 kHz
No. of useful Sub-carriers	1728
The index of the first useful sub-carrier (K_{min})	160 (start from 1)
The index of the last useful sub-carrier	1888

(K_{max})	
Bandwidth	18.9954 MHz
DC sub-carrier	1024^{th} sub-carrier is not used

Table 3

A TDD switch unit is preferably at least one TDD slot. Switching in a 2 ms TDD slot as shown in Fig. 1 allows dynamic DL/UL channel resource allocation. The resource allocation for DL and UL depends on the traffic symmetry ratio between DL and UL and may also reduce the service latency requirement. In addition, this allows less storage required in PHY layer transmit and receive processing. The 2ms TDD slot also supports fast channel quality measurement of the change of the radio link condition, and fast power control loop response.

Example TDD OFDMA frame/slot structure parameters are listed below in Table 4.

Parameters	Value	Comments
Duration of Super-Frame (ms)	80	Network Synchronization
TDD Frames/Super-Frame	8	
Duration of TDD Frame (ms)	10	Radio Frame

TDD Slots/Frame	5	DL slot/UL slot
Duration of TDD Slot (ms)	2	Minimum TDD switch unit, Power Control, C/I Measurement
OFDM-Pair /TDD Slot	9 (plus 1 tail symbol)	Space-time coding
Duration of OFDM-Pair (μs)	210.4888	
Duration of TTG+RTG (μs)	105.6	Tx/Rx transition gap and Rx/Tx transition gap
OFDM Symbols/ OFDM-Pair	2	
Duration of OFDM Symbols (μs)	105.2444	OFDM modulation burst

Table 4

Fig. 2 is a block diagram of frame, slot and sub-channel structures with a flexible TDD slot allocation and tail symbol.

The allocation of AMC sub-channel and diversity sub-channel is preferably based on the OFDM pair; such an assignment may be determined by the BS or a network element in a communication network. In the example configuration of Fig. 2, the UL/DL switching point is fixed at every 4ms, slot 1 and slot 2 are assigned the DL, and slot 3 and slot 4

are assigned for the UL. However, an additional flexible switching point is assigned at the UL period of slot 4. Such an assignment can be used to adjust the DL/UL traffic symmetrical ratio and to allow slot 1 and slot 2 support nomadic DL users and slot 4 to support mobility DL user, as more fast CQI feedback is available.

One possible baseline design is 2048-Fast Fourier Transform (FFT) for a 20MHz channel, which may be scaled to smaller channel bandwidth as shown below in Table 5.

System Bandwidth (MHz)	20	10	5	2.5	1.25
FFT Size	2048	1024	512	256	128
Number of Used Sub-carriers	1728	864	432	216	108
Number of Bands per Symbol	48	24	12	6	3
Number of Bins per Band	4	4	4	4	4
Number of Sub-bins per Bin	3	3	3	3	3
Number of Tones per Sub-bin	3	3	3	3	3

Table 5

Downlink open loop transmission with multiple antennas at a BS can be configured by several transmission modes. Assuming that N_T is the number of transmit antennas at BS and N_R is the number of receive antennas at terminal SS, a MIMO configuration is denoted as $N_T x N_R$.

For MIMO down link transmission, space time coding is preferably employed. In one embodiment, a 4x4 quasi-orthogonal space time transmit diversity (QOSTTD) code is used as a mother code for space time coding, and can be punctured in time to optimize for different receive antenna configurations. The MIMO transmission and reception can be expressed by $Y=HF(S)$, where Y^{1xM} is the output of the MIMO channel, H^{MxNT} is a matrix of MIMO channel characteristics, $F(s)$ denotes the space time coding matrix for a complex input symbol $S=[s_1 \ s_2 \ \dots \ s_L]$ which is grouped as $S_1=[s_1 \ s_2 \ s_3 \ s_4]$, $S_2=[s_5 \ s_6 \ s_7 \ s_8]$ and $S_3=[s_9 \ s_{10} \ s_{11} \ s_{12}]$, and the rows of coding matrix $F(s)$ are the individual antenna transmission outputs.

For a 4x1 configuration: (STC Code Rate = 1)

$$F_{4x1}(S_1,S_2,S_3)=\begin{bmatrix} s_1 & -s_2^* & -s_3^* & s_4 & s_5 & -s_7^* & -s_8^* & s_6 & s_9 & -s_{12}^* & -s_{10}^* & s_{11} \\ s_2 & s_1^* & -s_4^* & -s_3 & s_6 & s_8^* & s_7^* & s_5 & s_{10} & -s_{11}^* & s_9^* & -s_{12} \\ s_3 & -s_4^* & s_1^* & -s_2 & s_7 & s_5^* & -s_6^* & -s_8 & s_{11} & s_{10}^* & s_{12}^* & s_9 \\ s_4 & s_3^* & s_2^* & s_1 & s_8 & -s_6^* & s_5^* & -s_7 & s_{12} & s_9^* & -s_{11}^* & -s_{10} \end{bmatrix}.$$

For 4x2 configuration (STC Code Rate = 2), in-time puncturing the columns 3&4, 7&8 and 11&12 of $F_{4x1}(S_1,S_2,S_3)$ gives

$$F_{4x2}(S_1,S_2,S_3)=\begin{bmatrix} s_1 & -s_2^* & s_5 & -s_7^* & s_9 & -s_{12}^* \\ s_2 & s_1^* & s_6 & s_8^* & s_{10} & -s_{11}^* \\ s_3 & -s_4^* & s_7 & s_5^* & s_{11} & s_{10}^* \\ s_4 & s_3^* & s_8 & -s_6^* & s_{12} & s_9^* \end{bmatrix}.$$

For a 4x4 configuration (STC Code Rate = 4, spatial multiplexing), columns 1, 3 and 5 of $F_{4x2}(S_1,S_2,S_3)$, are preferably punctured, to give

$$F_{4x4}(S_1,S_2,S_3)=\begin{bmatrix} s_1 & s_5 & s_9 \\ s_2 & s_6 & s_{10} \\ s_3 & s_7 & s_{11} \\ s_4 & s_8 & s_{12} \end{bmatrix}.$$

An SS is preferably configured to receive the transmission of space-time coding of any of F_{4x1} F_{4x2} F_{4x4} with respect to different receive antennas capability of the SS classes. These three modes can be applied to the AMC sub-channel and diversity sub-channel. In addition, the fast feedback channel to support the modes selection and adaptation are designed for both DL and UL.

For 2 transmit antennas, two transmission modes are preferably supported: space time transmit diversity and spatial multiplexing.

For 2x1 configuration: (STC Code Rate = 1)

$F_{2x1}(S_1,S_2)=\begin{bmatrix} s_1 & -s_2^* & s_3 & -s_4^* \\ s_2 & s_1^* & s_4 & s_3^* \end{bmatrix}$, which is the Alamouti space time transmit diversity (STTD).

For 2x2, 2x4 configuration: (STC Code Rate = 2), puncturing the even columns of F_{2x1} gives:

$F_{2x2,2x4}(S_1,S_2)=\begin{bmatrix} s_1 & s_3 \\ s_2 & s_4 \end{bmatrix}$. This is the spatial multiplexing (a.k.a. BLAST).

In a preferred embodiment, the SS is configured to receive transmission of space-time coding of F_{2x1} $F_{2x2,2x4}$ with

respect to different receive antennas capability of SS classes. These two modes can be applied to the AMC sub-channel and diversity sub-channel. In addition, the fast feedback channel to support mode selection and adaptation are preferably designed for both DL and UL.

For both AMC sub-channel and diversity sub-channel transmission, MIMO modes can be adaptively selected based on the channel quality indicator (CQI) and channel Eigen Indicator (CEI). The MIMO transmission mode, modulation and FEC coding are preferably jointly optimized based on certain CQI and CLI to achieve MIMO channel capacity. Examples of dynamic adaptive MIMO mode selection are provided below.

For 2x4 MIMO, DL MIMO mode adaptation may be defined as in Table 6.

CQI	1	2	3	4	5	6	7	8	9	10
FEC Code	1	2	3	4	5	3	4	5	3	4
Modulation	1	1	1	1	1	1	1	1	2	2
STC	1	1	1	1	1	2	2	2	2	2

Table 6

An example FEC coding and modulation set is defined in Table 7.

Index	1	2	3	4	5
FEC	R=1/5	R=1/3	R=1/2	R=2/3	R=4/5
Modulation	QPSK	16	64		

		QAM	QAM		
STC	STTD	SM			

Table 7

For 2x2 MIMO, Table 8 provides an example of DL MIMO mode adaptation.

CQI	1	2	3	4	5	6		7		8		9		10	
CEI	N/A	N/A	N/A	N/A	N/A	L	S	L	S	L	S	L	S	L	S
FEC	1	2	3	4	5	3	3	4	4	5	5	3	3	4	4
Modulation	1	1	1	1	1	1	2	1	2	1	2	2	3	2	2
STC	1	1	1	1	1	2	1	2	1	2	1	2	1	2	1

Table 8

In Table 8, L=Large, S=Small, and channel eigen indicator (CEI) is preferably defined as $CEI = \frac{\sum_{i,j} |\hat{h}_{ij}|^2}{N_T^2 \det(HH^*)}$. For the AMC sub-channel per-stream antenna (i.e. PARC) transmission, the composite CQI is preferably used $CQI_{PARC} = \log\det\left(I + \frac{CQI}{N_T} HH^*\right)$.

In accordance with another embodiment of the invention, mapping a user to a transmit antenna enables the network to exploit the time-frequency diversity and multi-user diversity. In addition, the mapping also allows

flexible radio resource management/allocation and provides different QoS based services.

Each user can be mapped onto a different sub-channel, e.g. the AMC sub-channel and diversity sub-channel. For Single Input Single Output (SISO) systems, user mapping is preferably dependent on the CQI only, while for the MIMO case, mapping is preferably dependent on the auxiliary metric CEI in addition to CQI.

Where there is an OFDM symbol associated with each antenna, each user may be first mapped onto one or multiple OFDM symbols and each OFDM symbol may then be mapped onto its associated antenna. In particular, such mapping also allows per-antenna rate control (PARC).

Each OFDM symbol may be mapped onto its associated antenna in the sub-carrier domain. For certain sub-carriers, if no specific user data is mapped, then a null assignment to such sub-carrier maybe fed into the corresponding antenna. A preferred embodiment of OFDM symbol and antenna mapping is shown in Fig. 3, in which the OFDM resource is illustrated for AMC sub-channel only.

For each individual user, the antenna mapping enables STTD, SM and PARC transmissions for either the AMC sub-channel or the diversity sub-channel. In one embodiment, a six mapping configuration can be applied to each individual user.

The uplink may include, for example, two modes: (1) STTD for dual transmit antenna capable SS and (2) Virtual-MIMO for single transmit antenna capable SS.

According to a preferred channel structure which supports MIMO transmission in UL, every eight consecutive

OFDM symbols and three consecutive sub-carriers are defined as an STC sub-block. For each STC sub-block, two pairs of pilot signals are preferably set to allow the UL coherent reception at BS (See Fig. 4). The sub-block is designed based on the minimum coherent time and coherent bandwidth. The STC sub-block is the smallest unit for the diversity channel. The STC sub-block is preferably time-frequency hopped and can be controlled by a pre-assigned hopping pattern, an example of which is described below.

Fig. 5 is a block diagram of an example MIMO-OFDM tile for UL SMC sub-channel. To support MIMO transmission in UL, every eight consecutive OFDM symbols and nine consecutive sub-carriers are defined as an AMC STC sub-block in the structure of Fig. 5. For each STC sub-block, there are five pairs of pilot set to allow the UL coherent reception at BS. The sub-block defines the smallest unit for the AMC sub-channel and is preferably allocated within the coherent time and coherent bandwidth.

The mapping of each user's dedicated STC sub-blocks is preferably spread over the time-frequency dimension by using a random hopping pattern. The channel coding block spans several hops to achieve diversity gain and inter-cell interference averaging.

Non-overlapping assignment of the STC sub-block among multiple UL users avoids mutual user interference. It is preferable to design an orthogonal hopping pattern to assign to the different users. The synchronous quadratic congruence codes $y_k = \mathrm{QCS}(a, \alpha, \beta, k, p)$ can be employed as follows:

$$y_k^{QCS} = [a(\alpha+k)^2+\beta] \bmod p$$
$$k = 0,..p-1$$
$$a = 1,...,p-1$$
$$\alpha,\beta = 0,...,p-1$$

Such a hopping pattern can be used for the control of intra-cell users. Another alternative is to use the following asynchronous quadratic congruence to control of the inter-cell user hopping: $y_k^{QCA} = [ak^2+bk+c] \bmod p$. In this case, hopping collision among the users can occur, but the number of simultaneous users can be increased compared the synchronous quadratic congruence hopping pattern. Table 9 shows an example set of synchronous time-frequency hopping codes, p = 7, α, β = 0,..,6.

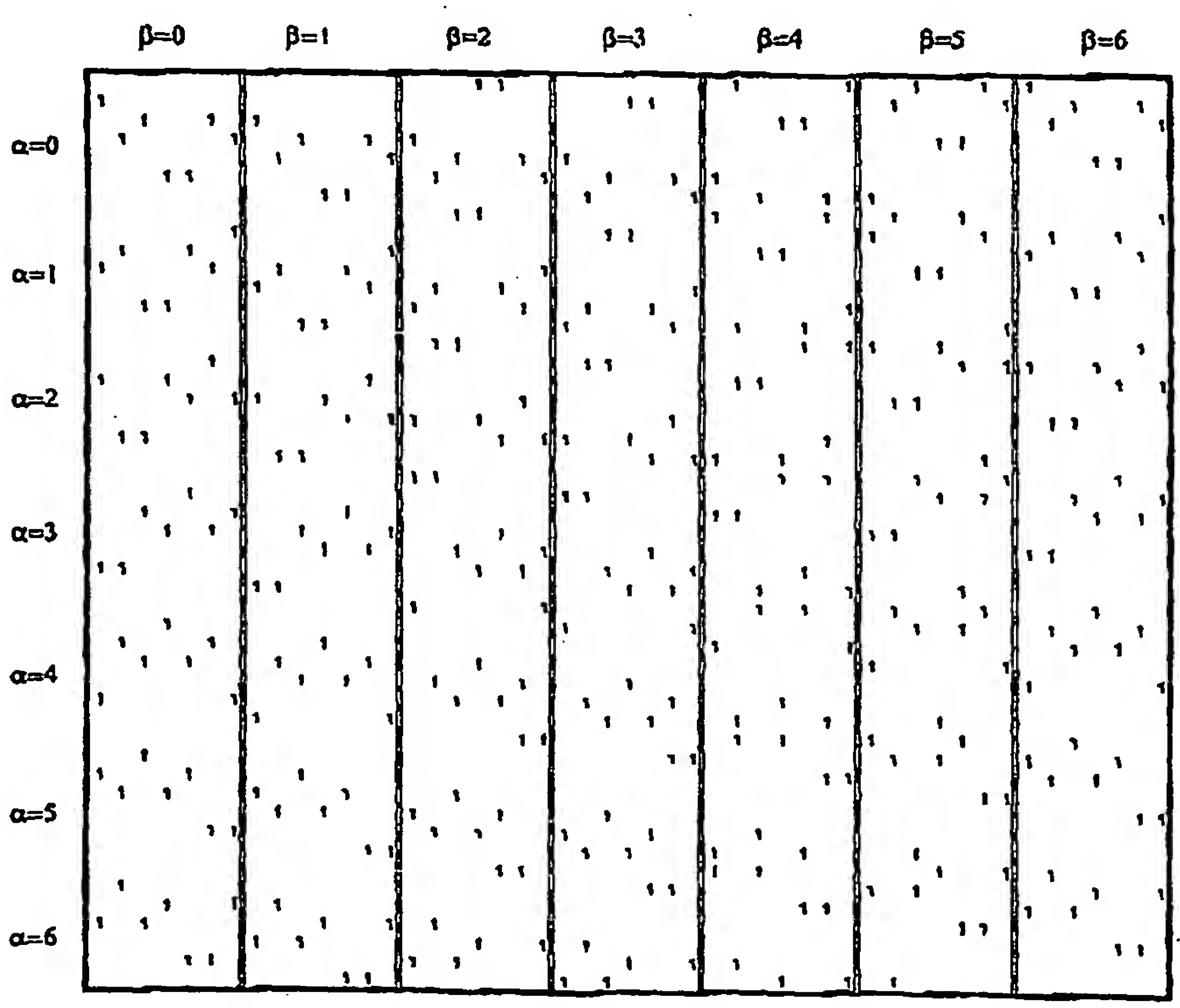


Table 9

The primary channels in the diversity sub-channel perform time-frequency hopping. The particular hopping pattern may be determined according to the parameters listed in Table 10.

Bandwidth (MHz)	20	10	5	2.5	1.25
FFT Size	2048	1024	512	256	128
Number of Bands per Symbol	48	24	12	6	3
Number of tiles per Band	36	36	36	36	36
Number of tiles per Symbol	1728	864	432	216	108
p				223	109
α, β					

Table 10

The parameter *a* is associated with the number of sector/beam, *a*=3 for tri-sector cell, *a*=11 for 9-beam cell, *a*=23 for 18-beam cell.

For a single antenna transmit SS, collaboration among SSs can be organized by a network to allow joint spatial multiplexing transmission in the UL. This is defined as virtual MIMO, and virtual MIMO can be configured for the diversity sub-channel and the AMC sub-channel.

Virtual MIMO for the diversity sub-channel is preferably configured by the network, with the network

assigning the different sub-block patterns, illustratively Pattern-A and Pattern-B as shown in Fig. 6, to two collaborative SSs. The pilot location for pattern-A and pattern-B are different, such that they jointly form two layered pilots to allow BS to jointly demodulate data from the two SSs by using a maximum likelihood (ML) decoder. The two collaborative SSs preferably use the same time-frequency hopping rule.

Virtual MIMO for the AMC sub-channel is similarly preferably configured by the network, with the network assigning different sub-block patterns, Pattern-A and Pattern-B in Fig. 7 for instance, to two collaborative SSs. As in Fig. 6, the pilot location for the pattern-A and pattern-B are different such that they jointly form a two layered pilot to allow BS to jointly demodulate data from the two SSs by using an ML decoder.

Since open loop power control is applied for all SSs in the TDD case, the long term receive signal strength for all SSs are on the same level. The grouping of the SSs user to form a collaborative virtual MIMO can be optimized by sub-MIMO selection criteria.

Hybrid ARQ based on the incremental redundancy transmission can be employed for both DL and UL. For the baseline SISO transmission, the Quasi Complementary Convolutional Turbo Code QCCTC incremental redundancy re-transmission can be used. For the MIMO/MISO transmission modes, for both UL and DL and for AMC sub-channel and diversity sub-channel, the space time coded incremental redundancy re-transmission may be applied.

An example transmission rule set for space time coded incremental redundancy codes for the 2-transmit MIMO case is listed in Table 11.

	Initial transmission	1^{st} re-transmission	2^{nd} re-transmission
Space time code incremental redundancy	$F(S_1)=\begin{bmatrix} s_1 & s_2 \\ s_3 & s_4 \end{bmatrix}$	$F(S_1)=\begin{bmatrix} -s_2^* & s_1^* \\ -s_4^* & s_3^* \end{bmatrix}$	$F(S_1)=\begin{bmatrix} s_1 & s_2 \\ s_3 & s_4 \end{bmatrix}$

Table 11

For the 4-transmit MIMO case, an example transmission rule set for space time coded incremental redundancy codes is listed in Table 12:

	Initial transmission	1^{st} re-transmission	2^{nd} re-transmission
Space time code incremental redundancy	$F(S_1,S_2)=\begin{bmatrix} s_1 & s_5 \\ s_2 & s_6 \\ s_3 & s_7 \\ s_4 & s_8 \end{bmatrix}$	$F(S_1,S_2)=\begin{bmatrix} -s_5^* & s_1^* \\ -s_6^* & s_2^* \\ -s_7^* & s_3^* \\ -s_8^* & s_4^* \end{bmatrix}$	$F(S_1,S_2)=\begin{bmatrix} s_1 & s_5 \\ s_2 & s_6 \\ s_3 & s_7 \\ s_4 & s_8 \end{bmatrix}$

Table 12

The SS preferably processes the initial transmission, 1^{st} re-transmission and 2^{nd} re-transmission in the form of space time decoding based on the Alamuoti

structure. The re-transmission of FEC code word may use the Chase combing re-transmission version.

In a framework according to an embodiment of the invention, backward compatibility is supported in that older SS equipment may access the network using TDM based on the network time slot allocation and planning. To enhance the DL transmission for such an SS, the delay-transmit-diversity can be applied with multiple transmission antennas at BS.

For DL AMC sub-channel, the BS antenna configuration may be assisted by SS measurement. For an SS with a single reception antenna, the SS is preferably configured to perform the closed loop 4x1 MISO, such as shown in Fig. 8.

Feedback information channel can be configured as shown below in Table 13, for example.

TxAA feedback	000	001	010	011	100	101	110	111
1-bit	0	$\pi/2$						
2-bit	0	$\pi/4$	$\pi/2$	$3\pi/4$				
3-bit	0	$\pi/8$	$\pi/4$	$3\pi/8$	$\pi/2$	$5\pi/8$	$3\pi/4$	$7\pi/8$

Table 13

For 2x1 MISO transmissions, the OFDM pre-coded waveform in the time-domain can support the single antenna SS reception for the DL spatial multiplexing transmission. The single antenna receiver performs ½ space fractional sampling and arrangement the even sample and odd samples as

two distinct receive chain to perform the ML decoding of spatial multiplexing. The same scheme can be used for the dual antenna receive SS to achieve 2x4 MIMO SM reception.

Fig. 9 is a block diagram of a transmit system for 2x2, 2x4 MISO/MIMO transmission.

For a DL 4x2 MIMO system,

$$H = \begin{bmatrix} h_{11} & h_{12} & h_{13} & h_{14} \\ h_{21} & h_{22} & h_{23} & h_{24} \end{bmatrix}.$$

By defining

$$H_{12} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} H_{13} = \begin{bmatrix} h_{11} & h_{13} \\ h_{21} & h_{23} \end{bmatrix} H_{23} = \begin{bmatrix} h_{12} & h_{13} \\ h_{22} & h_{23} \end{bmatrix} \quad H_{14} = \begin{bmatrix} h_{11} & h_{14} \\ h_{21} & h_{24} \end{bmatrix} H_{34} = \begin{bmatrix} h_{13} & h_{14} \\ h_{23} & h_{24} \end{bmatrix},$$ and

selecting the sub-system H_{ij} that satisfies

$$|\det(H_{ij})| = \max\{|\det(H_{12})|, |\det(H_{13})|, |\det(H_{23})|, |\det(H_{14})|, |\det(H_{34})|\},$$

the best mode of the 2x2 sub-MIMO system can be determined.

For a DL 4x2 MIMO system, consider six sub-MIMO systems H_{12}, H_{13}, H_{23}, H_{14} and H_{34}. Assuming that H_{ij}, H_{ik} and H_{il} are the Sub-MIMO systems that satisfy

$$|\det(H_{ij})| + |\det(H_{ik})| + |\det(H_{il})| = \max\{|\det(H_{ij})| + |\det(H_{ik})| + |\det(H_{il})|, |\det(H_{ij})| + |\det(H_{jk})| + |\det(H_{jl})|\}$$

then by beam-forming with the j^{th} and k^{th} columns of H, and setting the weights to

$$w_j = \frac{\det^*(H_{ij})}{\sqrt{|\det^*(H_{ij})|^2 + |\det^*(H_{ik})|^2 + |\det^*(H_{il})|^2}},$$

$$w_k = \frac{\det^*(H_{ik})}{\sqrt{|\det^*(H_{ij})|^2 + |\det^*(H_{ik})|^2 + |\det^*(H_{il})|^2}}$$

$$w_l = \frac{\det^*(H_{il})}{\sqrt{|\det^*(H_{ij})|^2 + |\det^*(H_{ik})|^2 + |\det^*(H_{il})|^2}}$$

then we have

$$\det(H_{ij}^{(AB)}) = \sqrt{\left|\det{}^{*}(H_{ij})\right|^2 + \left|\det{}^{*}(H_{ii})\right|^2 + \left|\det{}^{*}(H_{ii})\right|^2}\ .$$

A 4x2 sub-MIMO BLAST system using such weighting factors is shown in Fig. 10.

For closed loop implementation of MISO transmission, pre-coding matrix weighting in frequency-domain can be applied for 4x2x2 (N_T=4 for 2 SS each with N_R=4) or 4x1x4 (N_T=4 for 4 SS each with N_R=1) transmission, as shown in Fig. 11. This configuration can be employed in the TDD, by applying the "dirty-paper" encoding principle, and inter-user interference is pre-cancelled by transmit weighting matrixes G_1 and G_2.

Tables 14, 15, and 16 respectively list SS classes, SS capabilities, and new preferred receiver capabilities associated with embodiments of the invention.

DL: OL-STTD/SM, CL-STTD UL: SIMO, Virtual MIMO (N_T=1) MIMO, STTD (N_T=2)		SS antenna configuration		
		N_R=1	N_R=2	N_R=4
BS antenna configuration	N_T=1	SISO	SIMO	SIMO
	N_T=2	OL: STTD/MISO CL: Sub-MIMO/MISO	OL: STTD/SM CL: A-MIMO	OL: STTD/SM CL: A-MIMO
	N_T=4	OL: STTD/MISO CL: Sub-MIMO/MISO	OL: STTD/MISO CL: Sub-MIMO/MISO	OL: STTD/SM CL: A-MIMO

Table 14

DL: OL-STTD/SM, CL-STTD UL: SIMO, Virtual MIMO		SS antenna configuration		
		$N_R=1$	$N_R=2$	$N_R=4$
BS antenna configuration	$N_T=1$	SISO	SIMO (MRC)	SIMO (MRC)
	$N_T=2$	Recever # 1&2	Recever # 1, 2& 3	Recever # 1&3
	$N_T=4$	Recever # 4	Recever # 3&5	Receiver # 6

Table 15

Receiver #1	Receiver #2	Receiver #3	Receiver #4	Receiver #5	Receiver # 6
2x1 STTD	2x1 MISO	2x2/2x4 SM MLD	4x1 STTD	4x2 STTD	4x4 SM MLD

Table 16

The algorithm description of the algorithms in Table 16 are listed in Appendix A.

Standardization of a MIMO-OFDMA receiver capability in an SS enables the realization a broadband air interface with very high spectral efficiency.

A preamble is preferably allocated at each DL transmission frame. The example preamble of Fig. 12 includes two identical header symbols.

It is generally desirable that the preambles transmitted from different antennas are mutually orthogonal, to achieve better performance of initial system access, synchronization, base station identification and selection, and channel estimation.

Mapping of preambles onto DL transmit antennas effectively groups the preambles in the frequency domain. A pair-wise antenna transmit is organized for 4 transmit antennas, that is the 4 transmit antenna are formed into two groups, as shown in Fig. 13. Space-frequency block coding is preferably applied to each group, and the head symbol is preferably identical.

According to an embodiment of the invention, the preamble specific PN sequence mapping is as follows:

Sub-Carrier	1	2	3	4	5	6	7	8
Antenna-1	PN(1)	-PN(2)*	0	0	PN(5)	-PN(6)*	0	0
Antenna-2	PN(2)	PN(1)*	0	0	PN(6)	PN(5)*	0	0
Antenna-3	0	0	PN(3)	-PN(4)*	0	0	PN(7)	-PN(8)*
Antenna-4	0	0	PN(4)	PN(3)*	0	0	PN(8)	PN(7)*

Table 17

PN sequence is a cell specific code (real or complex) having a length N.

A further embodiment of the invention relates to scattered pilot signals. N_{used} used carriers are partitioned into variable location pilot sub-carriers, TPS sub-carriers and data sub-carriers.

The variable location pilots include pilot sub-groups. The locations of pilot are preferably identical in a pair of OFDM symbols. For four transmit antennas partitioned into two groups, .e.g. antennas 1 and 3 as group-1 and antennas 2 and 4 as group-2, STBC is applied to each antenna group based on the OFDM symbol pair pilots. In a particular embodiment of the invention shown in Fig. 14, the locations of pilot pair is offset shifted every OFDM symbol pair and the pattern is repeated every 3 OFDM symbol-pair.

The location of the scattered pilot pattern is preferably cyclically shifted in time-frequency plane with respect to the cell/sector assignment. The cyclic scattered pilot-pair planning allows high performance channel response estimation for multi-cell scenario, and application of co-channel interference cancellation technique and soft-hand-off.

Dynamic power boost may also be applied to scattered pilots. The pilot power boots is modulation dependent to allow coherent detection under lower SNR, hence to increase the range. The offset pattern of the scattered pilot may be derived from $[ID_{cell}]$modulo12, where ID_{cell} is a positive integer assigned by MAC to identify the BS sector. In a one embodiment, there are 8 orthogonal scattered pilot offset patterns. In addition, the scattered pilot pattern allows the fast pilot extraction by using sub-FFT instead of the full size FFT to reduce the portal device power consumption. The FSCH can be demodulated and by using

decision feedback the FSCH can be converted into additional pilots to assist the channel estimation. The scattered pilot pattern for 4 transmit antennas can be used for 2 transmit antennas to increase the pilot density in the excessive delay spread environment, e.g. ITU VB channel.

Table 18 lists example orthogonal scattered pilot patterns.

	Pattern-0 (i=0)	Pattern-1 (i=1)	Pattern-2 (i=2)	Pattern-3 (i=3)	Pattern-4 (i=4)	Pattern-5 (i=5)	Pattern-6 (i=5)	Pattern-7 (i=5)
OFDM Pair-1 ($N^i_{OFFSET}(0)$)	0	1	2	3	4	5	6	7
OFDM Pair-2 ($N^i_{OFFSET}(1)$)	5	6	7	8	9	10	11	12
OFDM Pair-3 ($N^i_{OFFSET}(2)$)	11	12	13	14	15	16	1	2

Table 18

The scattered pilot pattern may be defined as:

$$SP^i_{k_1}(m) = N^i_{OFFSET,k_1}(m) + 16P_k$$
$$SP^i_{k_1}(m) = N^i_{OFFSET,k_2}(m) + 16P_k$$
$$N^i_{OFFSET,k_1}(m) = \left(N^0_{OFFSET}(m) + i\right)\bmod 16$$
$$N^i_{OFFSET,k_2}(m) = \left(N^i_{OFFSET}(m) + 8\right)\bmod 16$$

where:

$SP^i_{k_1}$ is the sub-carrier index of variable-location pilots for antennas 1&3;

$SP^i_{k_2}$ is the sub-carrier index of variable-location pilots for antennas 2&4;

$N^{i}_{OFFSET}(m)$ is the sub-carrier indices offsets for m^{th} OFDM-pair and i^{th} rotation pattern from Table ;

$M=[0,1,2]$ is a modulo 3 function of the OFDM-pair;

$P_k=[0,1,2\ldots,N_{varLocPilot}-1]$, $N_{varLocPilot}$ is the number of variable location pilots for each antenna-pair; and

$I=[0,1,2,\ldots 11]$ is the pilot pattern index.

An example cyclic shift scattered pilot pattern is shown in Fig. 15.

The scattered pilot may be concatenated or mapped by STTD code and cell/sector/beam specific PN sequence. An example mapping of the STTD code for the scattered pilot is shown in Fig. 16.

The STTD encoding of the scattered pilot allows assisting several receiver specific operations such as channel estimation and frequency offset estimation. The PN encoded scattered pilot allows inter-cell interference averaging and cell/sector/beam identification, and channel quality indicator estimation, for instance.

Illustrative example scattered pilot parameters for 2048-OFDM with 20MHz bandwidth are listed in Table 19.

Parameter	Value
Number of dc carriers	1
Number of guard carriers, left	159
Number of guard carriers,	160

right	
N_{used}, Number of used carriers	1728
Total number of carriers	2048
Number of variable-location pilot	288 (for 4 transmit antennas); 144 (for 2 transmit antennas)
Number of data carriers	1440 (for 4 transmit antennas) 1584 (for 2 transmit antennas)
Number of FSCH carriers	108
Number of variable-location pilots which coincide with FSCH	108 (for 4 transmit antennas) 54 (for 2 transmit antennas)
Number of FSCH patterns	8
The frequency offset indices	32n+4k & 32n+4k+1

of FSCH sub-carriers	n=0, 1, ..., 53; k = 0, 1, ..., 8

Table 19

According to an aspect of the invention, the scattered pilot power is boosted based on the modulation transmission over the OFDM symbol. A power assignment for pilot and modulation constellation is listed in Table 20 and shown in Fig. 17

Constellations	Physical Channel	Modulation Relation w.r.t. Pilot Symbol
QPSK	Scattered Pilot	Same power as scattered pilot symbol
QPSK	Preamble	Same power as scattered pilot symbol
QPSK	Traffic	6dB less power than scattered pilot symbol
16QAM	Traffic	Same maximum amplitude as scattered pilot symbol
64QAM	Traffic	Same maximum amplitude as scattered pilot symbol

Table 20

According to a preferred embodiment of the invention, the DL 2048 OFDM symbol consists of 48 bands, each sub-band consists of 4 bands, each band consists of 9

sub-bands, and the sub-bands consists of nine consecutive sub-carriers. Other symbol and band dimensions are listed in Table 21.

System Bandwidth (MHz)	20	10	5	2.5	1.25
FFT Size	2048	1024	512	256	128
Number of Bands per Symbol	48	24	12	6	3

Table 21

Denote $x(n)\big|_{n=0,1,\cdots,N-1}$ a receive the OFDM symbol with $N=2^m$, and $X(k)\big|_{k=0,1,\cdots,N-1}$ be the FFT of $x(n)$. The diversity sub channel is preferably mapped onto the sub-carriers $X(k_o+k'2^p)\big|_{k'=0,1,\cdots,N'-1}$, where $0<p<m$, and $k_o<2^p$. A subset FFT computing can be applied to sub-carriers $X(k_o+k'2^p)$.

For the fundamental sub-channel ($k_o=0$), this reduces the computation of $x(n')$ into its simplest case:

$$x(n')=\sum_{l=0}^{2^p-1}x(n'+l\cdot N') \qquad n'=0,1,\cdots,N'-1,$$

in which no multiplication is required.

Similarly, for primary sub-channels ($k_o=2^{p-1}$), this reduces the computation of $x(n')$ into:

$$x(n')=e^{-j\pi n'/N'}\sum_{l=0}^{2^p-1}(-1)^l x(n'+l\cdot N') \qquad n'=0,1,\cdots,N'-1,$$

and a total of N' multiplications are required in computing $x(n')$.

The complexity of a sub-FFT of order n, compared to that of a full FFT of order p, is illustrated in the following Table 22 for different typical values of the FFT size N and of the sub-FFT bin spacing $2^{(n-p)}$.

		FFT Size N		
		512	1024	2048
Sub-FFT Spacing $2^{(n-p)}$	8	45.9%	46.9%	31.0%
	16	42.6%	40.3%	28.1%
	32	40.7%	38.7%	25.9%

Table 22

The sub-FFT construction of the diversity sub-channel allows reducing the FFT computing and channelling estimation computational complexity. This directly translates the battery saving for the portable device. The saving for the sub-FFT allows the processing of the FFT for MIMO, since to compute one full FTT is almost equivalent to compute 4 sub-FFT operations for the 4-receive MIMO.

The fundamental sub-channel is the adjacent sub-carrier to the scattered pilot pair. For each sector/beam, the location of the fundamental channel offset value is based on the scattered pilot offset; preferably the fundamental channel is adjacent to the scattered pilot. The

fundamental channel is preferably used for the purpose of safety channel which is not assigned by the BS but is reserved for the network assignment. The safety channel for different beams can be generated via the cyclic rotation of the fundamental channel to yield the other primary channel.

The time-frequency offset of the fundamental channel constitutes the primary sub-channels. Joint of primary channels can be used to construct variable rate diversity sub-channels. See Fig. 18. Adaptive coding modulation can be applied to the diversity sub-channels, since the grouping of the primary sub-channel is basically determined by the service data rate requirement and the SS geometry in the cell. The variation of the data rate or the composition of the diversity sub-channels may be in the vicinity of a certain tree node. An advantage of the dyadic tree representation of the composition of diversity sub-channel allows reduction of the signalling overhead.

The sub-channel construction can be considered a decomposition of full-band AMC sub-channel into diversity sub-channels. The fundamental channels are used as safety channel, for each sector beam the location of the fundamental channel is determined by the cyclic offset of the scattered pilot. The primary channels can be combined into variable rate diversity sub-channels. See Fig. 19. To achieve the adjacent cell/beam interference avoidance and averaging, a GF based hopping sequence is preferably applied to the primary channels if the adjacent cell/beam is not fully loaded, then the inter-cell/beam interference can be avoided.

$$y_k^{qcs} = [a(\alpha + k)^2 + \beta] \bmod p$$
$$k = 0,..p-1$$
$$a = 1,..,p-1$$
$$\alpha, \beta = 0,...,p-1$$

An example composition structure of the diversity sub-channel is shown in Fig. 19.

The diversity channel set preferably supports four types of sub-channels listed in Table 23.

Channel type	Physical Resource
Shared channel	TDM/FDM assigned and schedule by BS scheduler
Dedicated channel	FDM assigned to specific SS and rate adaptation
Common channel	FDM Broadcast multi-cast channel fixed power and data rate
Reserved channel	Safety channel

Table 23

The up link is preferably OFDMA multiplexed with multiple users mapped onto the same OFDM symbol. In one example embodiment, total N_{used} useful sub-carriers are first partitioned into sub-channels. Each sub-channel is a basic transmission unit. Each SS is assigned to several sub-channels; the sub-channel can be either diversity sub-channel or AMC sub-channel. The network can also dynamically allocate channel resource.

In a preferred embodiment, the diversity sub-channel includes a set of 3 contiguous sub-carriers through 8 contiguous symbols, as shown in Fig. 4. For one transmit antenna, the tile may include 22 data sub-carriers and 2 pilot sub-carriers. For two collaborating SSs, there are two different pilot patterns. The pilot pattern offset allows performing of UL Virtual spatial multiplexing and also allows the pilot power boost. Each SS selects one of the pilot patterns according to the message for the BS when UL virtual spatial multiplexing is applied.

Pilot pattern selection may be based on the following rules:

(1) for the two single antenna receive collaborative SS to perform virtual MIMO, SS with odd number of ID_{cell} choose pattern 1 and SS with even number of ID_{cell} choose pattern 2

(2) For the SS with dual transmit antennas selects the pilot diversity sub-channel with 20 data sub-carriers and 4 pilot sub-carriers.

For the AMC sub-channel, N_{used} used sub-carriers are preferably first partitioned into bands, each having 4 bins. Each bin is constructed by 3 contiguous sub-bins (tile). The bin is the smallest DL AMC sub-channel unit. For single transmit antenna, each bin may have 67 data sub-carriers plus 5 pilot sub-carriers. The AMC sub-channel preferably has at least two different pilot patterns. The pilot pattern offset allows performing of UL Virtual spatial multiplexing and also allows the pilot power boost. SS selects one of the pilot patterns according to the message for the BS when UL

virtual spatial multiplexing is applied. The pilot pattern selection may be based on the following rules:

(1) for the two single antenna receive collaborative SS to perform virtual MIMO, SS with odd number of ID_{cell} choose pattern 1 and SS with even number of ID_{cell} choose pattern 2

(2) For the SS with dual transmit antennas select the pilot diversity sub-channel with 62 data sub-carriers + 10 pilot sub-carriers. Each SS can be assigned to multiple consecutive or discontinuous AMC sub-channels.

For a 20MHz channel 2048-FFT, preferred up-link resources are listed in Table 24.

Number of bands per OFDM symbol	48
Number of bins per band	4
Number of sub-bins per bin	3
Number of sub-carriers per sub-bin	3
Number of sub-carriers per bin	9

Table 24

Example UL OFDMA parameters are listed in Table 25.

Parameter	Value
Number of dc carriers	1
Number of guard carriers, left	159
Number of guard carriers, right	160
N_{used}, Number of used carriers	1728
Total number of carriers	2048
Number of pilots per sub-channel	4 (for 2 transmit antennas); 2 (for 1 transmit antennas)
Number of data carriers per sub-channel	20 (for 2 transmit antennas); 22 (for 1 transmit antennas)
Number of pilots per sub-band	12 (for 2 transmit antennas); 6 (for 1 transmit antennas)
Number of data carriers per sub-band	60 (for 2 transmit antennas); 66 (for 1 transmit antennas)

Table 25

Several fast MAC control channel are designed and mapped onto dedicated physical channels for both DL and UL

in accordance with aspects of the invention. These fast control channels enable the fast connection set up and fast link adaptation, and also allow fast H-ARQ re-transmission.

A basic concept of down link fast control channels according to embodiments of the invention is based on the following: (1) The FSCH is mapped onto the sub-FFT sub-carriers, therefore most of the time the full-FFT computing can be avoided if user-ID is not detected in the FSCH message, (2) the FSCH is a differential encoded, therefore the channel estimation is not required to decode the FSCH message, and (3) the FSCH is robust encoded to allow the detection of message in the very low CIR.

In one embodiment, a total 54 pairs of FSCH sub-carriers is allocated for each OFDM symbol, and the spacing between FSCH pair is 31 sub-carriers. The FSCH is preferably punctured over the scattered pilots so that they coincide at the same time-frequency location. The FSCH can be recoded as pilot channel to further reduce the scattered pilot overhead. According to a preferred embodiment, there are 8 different FSCH allocation patterns, for the adjacent cell/beam planning to avoid the interference, and the FSCH is 3dB power boosted to increase the reliability of FSCH detection and range. The frequency offset indices of FSCH sub-carriers in one embodiment follows:

$$\begin{matrix} 32n+4\times k & n=0,1,\ldots,53 \\ 32n+4\times k+1 & k=0,1,\ldots,8 \end{matrix}.$$

The FSCH is preferably encoded with differential STTD code, as:

$$Z_i=\frac{1}{\sqrt{2}}Z_{i-1}X_i \text{ where, } X_i=\begin{bmatrix} x_1 & x_2 \\ -x_2^* & x_1^* \end{bmatrix}.$$

The decoding of differentially encoded STTD code can be simplified into one step, the relation between the transmitted signal and the channel is multiplication. For 2x2 case, define:

m: OFDM symbol index in time

k: OFDM sub-carrier index

$s(2k)$: even number QAM symbols to form STBC symbol $z_{1,l}$

$s(2k+1)$: odd number QAM symbols to form STBC symbol $z_{2,l}$

$y_i(m,k)$: received signal at antenna $i=1,2$.

The transmitted STBC coded signal (i.e., before the differential encoder) at time m and $m+1$ is:

$$\begin{bmatrix} s(2k) & s(2k+1) \\ -s(2k+1)^* & s(2k)^* \end{bmatrix},$$

where the column number is in space domain, while the row number is in time domain.

With differential coding, the received signal at the two receiving antennas can be expressed as follows:

$$\begin{bmatrix} y_1(m,k) \\ y_1(m+1,k) \end{bmatrix} = \frac{1}{\sqrt{2}} \begin{bmatrix} s(2k) & s(2k+1) \\ -s(2k+1)^* & s(2k)^* \end{bmatrix} \begin{bmatrix} y_1(m-2,k) \\ y_1(m-1,k) \end{bmatrix}$$

$$\begin{bmatrix} y_2(m,k) \\ y_2(m+1,k) \end{bmatrix} = \frac{1}{\sqrt{2}} \begin{bmatrix} s(2k) & s(2k+1) \\ -s(2k+1)^* & s(2k)^* \end{bmatrix} \begin{bmatrix} y_2(m-2,k) \\ y_2(m-1,k) \end{bmatrix}.$$

From the above two equations, the maximum likelihood signals of $s(2k)$ and $s(2k+1)$ can be obtained as:

$$\tilde{s}(2k) = y_1(m-2,k)^* y_1(m,k) + y_1(m-1,k) y_1(m+1,k)^* + y_2(m-2,k)^* y_2(m,k) + y_2(m-1,k) y_2(m+1,k)^*$$

$$\bar{s}(2k+1)=y_1(m-1,k)^* y_1(m,k)-y_1(m-2,k)y_1(m+1,k)^* + y_2(m-1,k)^* y_2(m,k)-y_2(m-2,k)y_2(m+1,k)^* ,$$

or in a matrix form:

$$\begin{bmatrix}\bar{s}(2k)\\ \bar{s}(2k+1)\end{bmatrix}=\begin{bmatrix}y_1(m-2,k)^* & y_1(m-1,k)\\ y_1(m-1,k)^* & -y_1(m-2,k)\end{bmatrix}\begin{bmatrix}y_1(m,k)\\ y_1(m+1,k)^*\end{bmatrix}+\begin{bmatrix}y_2(m-2,k)^* & y_2(m-1,k)\\ y_2(m-1,k)^* & -y_2(m-2,k)\end{bmatrix}\begin{bmatrix}y_2(m,k)\\ y_2(m+1,k)^*\end{bmatrix}.$$

Defining

$$\delta^2=|y_1(m-2,k)|^2+|y_1(m-1,k)|^2+|y_2(m-2,k)|^2+|y_2(m-1,k)|^2 ,$$

then

$$\hat{s}(2k)=\bar{s}(2k)/(\sqrt{2}\delta^2) \qquad \hat{s}(2k+1)=\bar{s}(2k+1)/(\sqrt{2}\delta^2)$$

or

$$\begin{bmatrix}\hat{s}(2k)\\ \hat{s}(2k+1)\end{bmatrix}=\frac{1}{\sqrt{2}\delta^2}\begin{bmatrix}\bar{s}(2k)\\ \bar{s}(2k+1)\end{bmatrix}.$$

For FEC encoding and decoding strategy for FSCH,, a product code is preferably used for the FSCH block encoding by using two or more short block codes. An example product code $P=C_1\otimes C_2$ is shown in Fig. 20, where C_1 is a (n_1,k_1) linear code and C_2 is a (n_2,k_2) linear code. The resulting product code is a (n_1n_2,k_1k_2) linear code. If the code C_1 has minimum weight d_1 and the code C_2 has minimum weight d_2, the minimum weight of the product code is exactly d_1d_2. For a given code rate, to construct a product code with the maximum minimum weight, C_1 and C_2 are selected to have similar minimum weight. For the block of 45 bytes, i.e. $n_1n_2=360$, C_1 is preferably chosen as $(15,6)$ shortened code,

derived from an (16,7) extended BCH code, and C_2 is preferably chosen as a (24,13) shortened code, derived from a (32,21) BCH code. The minimum weight of this product code is larger than 36, the code rate is 0.217, with 78 information bits being encoded in each code word.

There are several product code decoders which can be employed, for example Wolf [ ] method can be used to perform optimum maximum likelihood decoder, which uses the Viterbi algorithm to decode a block code and/or a product code. Pyndiah [ ] iterative decoding algorithm using a Chase decoder [ ] to deliver soft outputs, thus reduces the complexity of the decoder.

Since each active SS detects FSCH message, if the message detection is incorrect, then the entire slot reception is failed. If the message is correctly demodulated, the MAC id is not detected, then there is no need to further demodulate the AMC or diversity sub-channels, hence also the channel estimation. The major receiver process can be saved to extend the battery life. However, the by using decision feedback of the correctly decoded FSCH message, an indirect channel quality measurement can be performed based on the FEC decoding of soft QAM de-mapped data. Since the objective of channel quality estimation is for a successful coding and modulation assignment, such a Channel Quality Indicator (CQI) can provide an overall quality of the channel, including interference, multi-path fading, and Doppler. The CQI can measure the quality of a received signal is to measure the average distance between the received signal and the reference QAM constellation. The weaker the signal, the more scattering and random is the received signal on the reference QAM constellation, therefore the larger the

average distance between the signal and its closest QAM reference. Advantageously, the soft output from QAM de-mapping can be used, since the amplitude of the soft output indicates the confidence of the signal. Substantially all the channel impairments may thus be consolidated into such an indicator.

For FSCH signals, the soft output bits from QAM-demapping are the conditional LLRs of a code word, and the inner product of such a soft output vector on the decoded code word can be used as a CQI. Since, for a data sequence coded with an (n,k) FEC code, only a subspace of dimension k (out of a space of dimension n) constitutes a code word space, namely, it is only the Euclidean distance between a received soft output vector and its closest vertex in the code word space which provides the likelihood of the decoded data, and hence the channel quality due to the fact that each received bit is not independent. By using this dependency between the coded bits, rather than individual bits in isolation, a much more accurate CQI estimation can be achieved.

Turning now to an embodiment of the invention for UL ranging, a UL frame starts with UL preamble, with the preamble including ranging sub-channel and control sub-channel. The UL ranging sub-channel preferably includes two 1024 OFDM symbols. The OFDM symbol following the preamble is preferably used as UL control channel. UL preamble is the minimum UL burst unit. The preamble burst enables fast access. The preamble power may be set based on open loop power control.

The UL ranging channel preferably includes three sub-channels: (1) random access channel (RACH), (2) periodic

ranging, and (3) bandwidth request. The total 864 sub-carriers in the header symbols are preferably partitioned into 27 ranging sub-bands. In a preferred embodiment, the ranging sub-bands are separated into two parts: (a) N ranging sub-bands for RACH (initial ranging) and N is a system parameter and is broadcast through DL broadcasting channel (even number) (b) the remaining 27-N ranging sub-channels are used as periodical ranging and bandwidth request. The mappings of RACH, periodical ranging and bandwidth request are different among adjacent cells to reduce the inter-cell interference.

For RACH modulation, a PN code with 32N bits, for example, is selected randomly from an initial ranging code set. The tones in the N ranging sub-bands in the first UL header symbol are then modulated with the PN code. The same code is applied to modulate the same ranging sub-bands in the second UL header symbol. Preferably, there is no phase discontinuity between the two header symbols for RACH. The ranging code is masked by a cell specific code.

For modulation of periodical ranging channel and bandwidth request channel, a ranging sub-band pair is preferably generated by two ranging sub-bands at the same position in the two header symbols. Illustratively, a PN code with 32N bits selected randomly from a periodical ranging/bandwidth request code set. 32N tones in N/2 ranging sub-band pairs are then modulated with the PN code.

LDPC code is preferably employed in the DL as forward error correction code. For the case of H-ARQ packet re-transmission, the LDPC the packet may be transmitted for the Chase combing a FEC codeword level, for example, and the

incremental redundancy may be generated during space time coding.

The LDPC encoder preferably includes systematic bits path and parity bit generation path, the parity generation preferably including three elements:

1. Table of the systematic part repetition;
2. Interleaver;
3. Table accumulation after interleaving.

Fig. 21 is a block diagram of an example LDPC encoder.

Within the encoder block size, an accumulation window may be fixed at every 7[th] output of the internal interleaver, for example. An example non-uniform repetition assignment is shown in Fig. 22.

Three additional differential modulations may be applied for the cases of SISO, MISO and MIMO transmission. These deferential modulations can be used for the data traffic both in DL and UL and for diversity sub-channel and AMC sub-channels to improve the lower SNR data service coverage. The modulation complex input symbol is denoted below as X_l; the differential modulation complex output symbol is denoted as Z_l.

For the SISO and SIMO retransmission and π/4-DQPSK modulation, an example input bit to symbol mapping is shown in Table 26.

Codeword b_0b_1	Modulation

	symbol, x_l
00	1
01	j
11	-1
10	-j

Table 26

For the MISO or MIMO case with 1,2 and 4 transmit antennas, differential space time coding examples are listed in Table 27.

Antenna Configuration	Modulation Rule	X_l
1-transmit antenna	$Z_l = \frac{1}{\sqrt{2}} Z_{l-1} X_l$	Table
2-transmit antenna	$Z_l = \frac{1}{\sqrt{2}} Z_{l-1} X_l$	$X_l = \begin{bmatrix} x_1 & x_2 \\ -x_2^* & x_1^* \end{bmatrix}$
4-transmit antenna	$Z_l = \frac{1}{\sqrt{2}} Z_{l-1} X_l$	$X_l = \begin{bmatrix} x_1 & x_2 & \frac{x_3}{\sqrt{2}} & \frac{x_3}{\sqrt{2}} \\ -x_2^* & x_1^* & \frac{x_3}{\sqrt{2}} & -\frac{x_3}{\sqrt{2}} \\ \frac{x_3^*}{\sqrt{2}} & \frac{x_3^*}{\sqrt{2}} & \frac{-x_1 - x_1^* + x_2 - x_2^*}{2} & \frac{x_1 - x_1^* - x_2 - x_2^*}{2} \\ \frac{x_3^*}{\sqrt{2}} & -\frac{x_3^*}{\sqrt{2}} & \frac{x_1 - x_1^* + x_2 + x_2^*}{2} & \frac{-x_1 - x_1^* - x_2 + x_2^*}{2} \end{bmatrix}$

Table 2

The SS is preferably capable of receiving the transmission of differential modulation with and without space-time coding with respect to different receive antennas capability of the SS classes.

A randomization mask may be used for syndrome-based PAPR reduction. The pseudo noise codes produced by the PRBS of Fig. 23, for example, are binary codes. The codes are generated by the polynomial $1+x^1+x^4+x^7+x^{15}$ and the PN mask for cell identification is generated by an M-sequence generator. The binary ranging codes are preferably subsequences of the pseudo noise sequence appearing at its output. The length of each ranging code is preferably in the range of a minimum 32 bits to maximum 256 bits.

A generated PAPR randomize mask, as generated from the PRBS shown in Fig. 23, for example, is applied to a packet into the FEC encoder prior a CRC operation.

For network radio resource planing and mobility management, any of the following physical layer parameters may be used: Scattered pilot, Preamble, Diversity Sub-channel, Soft handoff, F-SCH, and Up link pilot.

For an open-loop MIMO system, when $N_{Tx} > N_{Rx}$, we may apply STTD or OQ-STTD to achieve diversity and/or improved throughput. However, for a 4×2 system, decoding a OQ-STTD codeword will need to compute a 4×4 matrix inverse. To simplify the decoder structure, we may consider OFDM based grouped antenna transmit diversity (GATD), in which pairs of the 4 antennas are respectively associated with the 2 antennas. Assuming that the 4×2 system is defined by

channel matrix $A=\begin{bmatrix}\alpha_{11} & \alpha_{12} & \alpha_{13} & \alpha_{14}\\ \alpha_{21} & \alpha_{22} & \alpha_{23} & \alpha_{24}\end{bmatrix}$, and all the elements in A are independent to each other, then $\begin{matrix}h_{11}=\alpha_{11}+\alpha_{12}\\ h_{12}=\alpha_{13}+\alpha_{14}\\ h_{21}=\alpha_{21}+\alpha_{22}\\ h_{22}=\alpha_{23}+\alpha_{24}\end{matrix}$. The equivalent 2×2 system is then defined by $H=\begin{bmatrix}h_{11} & h_{12}\\ h_{21} & h_{22}\end{bmatrix}$. By employing V-BLAST, the receiver only computes a 2×2 matrix inverse. From the second equation above, it can be seen that this approach introduces frequency selectivity into the system, and since each path is used for signal transmission, diversity order is maintained.

This approach is specific to OFDM, which is able to collect signal energy perfectly from multi-paths as long as the delay spread is smaller than the cyclic prefix.

What has been described is merely illustrative of the application of the principles of the invention. Other arrangements and methods can be implemented by those skilled in the art without departing from the spirit and scope of the present invention.

For example, the drawings and the foregoing description are intended solely for illustrative purposes. It should therefore be appreciated that the invention is in no way limited thereto.

APPENDIX A: RECEIVER ALGORITHMS

The following six receiver algorithms may be used to support MIMO-OFDMA.

1. Receiver #1

$$\begin{bmatrix} s_1 \\ s_2 \end{bmatrix} = \frac{\begin{bmatrix} h_1 & h_2 \\ h_2^* & -h_1^* \end{bmatrix}}{\sqrt{|h_1|^2 + |h_2|^2}} \begin{bmatrix} r_1 \\ r_2 \end{bmatrix}$$

2. Receiver #2

Same as receiver #3

3. Receiver #3

Table 3 Complexity of 2x4 MIMO MLD decoder

	ZF	Subset MLD	MLD (text book)
Multiplication	616	5,704	3.36E+07
Complex division	1	4	
Division	1	5	
Compare & select		256	6.71E+07

4. Receiver #4

4x1 MISO receiver algorithm

- STEP-1

$$A = |h_1|^2 + |h_2|^2 + |h_3|^2 + |h_4|^2$$
$$B = 2\,\mathrm{Re}(h_1^* h_4) - 2\,\mathrm{Re}(h_2^* h_3)$$

- STEP-2

$$\begin{bmatrix} s_1 \\ s_2 \\ s_3 \\ s_4 \end{bmatrix} = \begin{bmatrix} A & 0 & 0 & B \\ 0 & A & -B & 0 \\ 0 & -B & A & 0 \\ B & 0 & 0 & A \end{bmatrix} \begin{bmatrix} r_{1,1} \\ r_{2,1} \\ r_{1,2}^* \\ r_{2,2}^* \end{bmatrix}$$

---

5. **Receiver # 5**

<u>4x2 MISO receiver algorithm</u>

- STEP-1

$$A = |h_{1,1}|^2 + |h_{2,1}|^2 + |h_{1,2}|^2 + |h_{2,2}|^2$$
$$B = |h_{1,3}|^2 + |h_{2,3}|^2 + |h_{1,4}|^2 + |h_{2,4}|^2$$
$$C = h_{1,1}^* h_{1,3} + h_{2,1}^* h_{2,3} + h_{1,2} h_{1,4}^* + h_{2,2} h_{2,4}^*$$
$$D = h_{1,1}^* h_{1,4} + h_{2,1}^* h_{2,4} - h_{1,2} h_{1,3}^* - h_{2,2} h_{2,3}^*$$
$$E = h_{1,2}^* h_{1,3} + h_{2,2}^* h_{2,3} - h_{1,1} h_{1,4}^* - h_{2,1} h_{2,4}^*$$
$$F = h_{1,2}^* h_{1,4} + h_{2,2}^* h_{2,4} + h_{1,1} h_{1,3}^* + h_{2,1} h_{2,3}^*$$

- STEP-2

$$\begin{bmatrix} s_1 \\ s_2 \\ s_3 \\ s_4 \end{bmatrix} = \begin{bmatrix} A & 0 & C & D \\ 0 & A & E & F \\ F & -D & B & 0 \\ -E & C & 0 & B \end{bmatrix} \begin{bmatrix} r_{1,1} \\ r_{2,1} \\ r_{1,2}^* \\ r_{2,2}^* \end{bmatrix}$$

---

6. Receiver #6

Table 4 Complexity of 4x4 MIMO MLD decoder

	ZF	Subset MLD	MLD (text book)
Multiplication	616	5,704	3.36E+07
Complex division	1	4	
Division	4	5	
Compare & select		256	6.71E+07

We Claim:

1. A method/system/network element in a communication network/communication terminal configured to adaptively select any one of a plurality of operating modes, the plurality of operating modes comprising at least two modes selected from the group consisting of: Time Division Multiplexing (TDM), TDM/Frequency Division Multiplexing (FDM), TDM/FDM/MIMO fractional time/frequency reuse sub-channels, TDM/FDM/MIMO Adaptive Modulation and Coding (AMC) sub-channel mapping, diversity sub-channel mapping, TDM/FDM/MIMO adaptation of modulation and Forward Error Correction (FEC) coding with fast antenna sub-MIMO selection, TDM/FDM/MIMO joint adaptation of space time coding modulation and FEC coding, closed loop MIMO, and open loop MIMO.

2. A TDD frame structure comprising:

a plurality of slots;

fixed switching points; and

flexible switching points,

wherein a direction of communications may be switched at any of the fixed or flexible switching points.

3. A method/system for constructing/processing the frame structure of claim 2.

4. A method comprising:

mapping a communication signal to be transmitted to one of a plurality of users onto a transmission symbol; and

mapping the transmission symbol onto one of a plurality of antennas.

5. The method of claim 4, wherein communication signals for each user are mapped onto a different sub-channels.

6. The method of claim 5, wherein the different sub-channels comprise an AMC sub-channel and a diversity sub-channel.

7. The method of claim 4, wherein the first step of mapping is dependent on at least one of CQI and CEI.

8. The method of claim 4, wherein the transmission symbol is an OFDM symbol.

9. The method of claim 4, further comprising:

performing per-antenna rate control (PARC).

10. The method of claim 5, wherein the different sub-channels comprise a sub-channel with no mapped communication signal, further comprising:

mapping a null assignment to the sub-channel with no mapped communication signal.

11. A system for performing the method of any of claims 4-10.

12. Receive side system/methods for claims 4-11.

13. A method comprising:

defining as an STC sub-block comprising a number of consecutive symbols and a number of consecutive sub-carriers;

setting pairs of pilot signals in each STC-sub-block.

14. The method of claim 13, for an uplink diversity channel.

15. The method of claim 14, wherein the number of consecutive symbols is eight, the number of consecutive sub-carriers is three, and two pairs of pilot symbols are set.

16. The method of claim 13, wherein setting comprises setting as shown in Fig. 4.

17. The method of claim 13, for an uplink AMC channel.

18. The method of claim 17, wherein the number of consecutive symbols is eight, the number of consecutive sub-carriers is nine, and five pairs of pilot symbols are set.

19. The method of claim 13, wherein setting comprises setting as shown in Fig. 5.

20. The method of claim 13, further comprising:

time-frequency hopping the STC sub-block according to a hopping pattern.

21. The method of claim 13, wherein defining comprises defining a plurality of STC sub-blocks patterns, further comprising:

configuring virtual MIMO for a plurality of users by assigning different sub-block patterns to different users.

22. The method of claim 21, wherein the plurality of sub-block patterns comprises the patterns of Fig. 6 and/or Fig. 7.

23. A system for performing the method of any of claims 13-22.

24. Receive side systems/methods for the method of any of claims 13-22.

25. A MIMO Hybrid ARQ system/method for 4 transmit antennas using the retransmission rule of Table 12.

26. A system/method of tuning antennas at a transmitter, comprising:

receiving 1-, 2- or 3-bit feedback channel information; and

mapping the feedback information to a phase shift as shown in Table 13.

27. A system/method of sub-MIMO selection, comprising:

defining $H_{12}=\begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} H_{13}=\begin{bmatrix} h_{11} & h_{13} \\ h_{21} & h_{23} \end{bmatrix} H_{23}=\begin{bmatrix} h_{12} & h_{13} \\ h_{22} & h_{23} \end{bmatrix}$ $H_{14}=\begin{bmatrix} h_{11} & h_{14} \\ h_{21} & h_{24} \end{bmatrix} H_{34}=\begin{bmatrix} h_{13} & h_{14} \\ h_{23} & h_{24} \end{bmatrix}$; and

selecting the sub-MIMO system H_{ij} that satisfies

$$\left|\det(H_{ij})\right| = \max\left\{\left|\det(H_{12})\right|, \left|\det(H_{13})\right|, \left|\det(H_{23})\right|, \left|\det(H_{14})\right|, \left|\det(H_{34})\right|\right\}.$$

28. A system/method of sub-MIMO selection, comprising:

selecting sub-MIMO systems H_{ij}, H_{ik} and H_{il} are the Sub-MIMO systems that satisfy

$$\left|\det(H_{ij})\right| + \left|\det(H_{ik})\right| + \left|\det(H_{il})\right| = \max\left\{\left|\det(H_{ij})\right| + \left|\det(H_{ik})\right| + \left|\det(H_{il})\right|, \left|\det(H_{ij})\right| + \left|\det(H_{jk})\right| + \left|\det(H_{jl})\right|\right\}$$

; and

beam-forming with the j^{th} and k^{th} columns of H, and setting the weights to

$$w_j = \frac{\det^*(H_{ij})}{\sqrt{\left|\det^*(H_{ij})\right|^2 + \left|\det^*(H_{ik})\right|^2 + \left|\det^*(H_{il})\right|^2}},$$
$$w_k = \frac{\det^*(H_{ik})}{\sqrt{\left|\det^*(H_{ij})\right|^2 + \left|\det^*(H_{ik})\right|^2 + \left|\det^*(H_{il})\right|^2}}$$
$$w_l = \frac{\det^*(H_{il})}{\sqrt{\left|\det^*(H_{ij})\right|^2 + \left|\det^*(H_{ik})\right|^2 + \left|\det^*(H_{il})\right|^2}}$$

with $\det(H_{ij}^{(jkl)}) = \sqrt{\left|\det^*(H_{ij})\right|^2 + \left|\det^*(H_{ik})\right|^2 + \left|\det^*(H_{il})\right|^2}$.

29. The method/system of claim 27 or 28, for other dimensions of sub-MIMO systems.

30. A method/system of selecting an operating mode as defined in Tables 14 and/or 15.

31. A system/method of providing cell/beam-specific preambles by mapping specific PN codes to respective antennas.

32. A method/system comprising/configured for:

scattering and coding pilot signals as in Figs. 14-16 and Table 18.

33. A method/system comprising/configured for:

allocating power to a scattered pilot channel as in Table 20 and Fig. 17.

34. A method/system comprising/configured for:

defining diversity and/or AMC sub-channels to simplify FFT computation.

35. A method/system comprising/configured for:

constructing sub-channels as in Figs. 18/19 and Table 23.

36. A method/system comprising/configured for:

providing fast uplink and/or downlink control channels.

37. The method/system of claim 36, wherein providing comprises allocating 54 pairs of FSCH sub-carrier for each OFDM symbol.

38. The method/system of claim 37, wherein the spacing between FSCH pair is 31 sub-carriers.

39. The method/system of claim 37, wherein the FSCH is punctured over the scattered pilots so that they coincide at the same time-frequency location.

40. The method/system of claim 39, wherein the FSCH is recoded as pilot channel to reduce pilot overhead.

41. The method/system of claim 37, wherein there are 8 different FSCH allocation patterns, the FSCH is 3dB power boosted to increase reliability of FSCH detection and range, and/or the frequency offset indices of FSCH sub-carriers are:

$$\begin{array}{ll} 32n+4\times k & n=0,1,\ldots,53 \\ 32n+4\times k+1 & k=0,1,\ldots,8 \end{array}$$

42. A method/system comprising/configured for:

providing a ranging channel.

43. The method/system of claim 42, further comprising/configured for:

modulating the ranging channel.

44. A method/system comprising/configured for:

providing a configurable LDPC encoder.

45. A method/system comprising/configured for:

additional differential modulation for range extension.

46. A communication method/system comprising/configured for operation with any of the receivers #1-#6 of appendix A.

47. A method/network comprising a combination of transmit and receive side methods/systems/structures in any of the preceding claims.

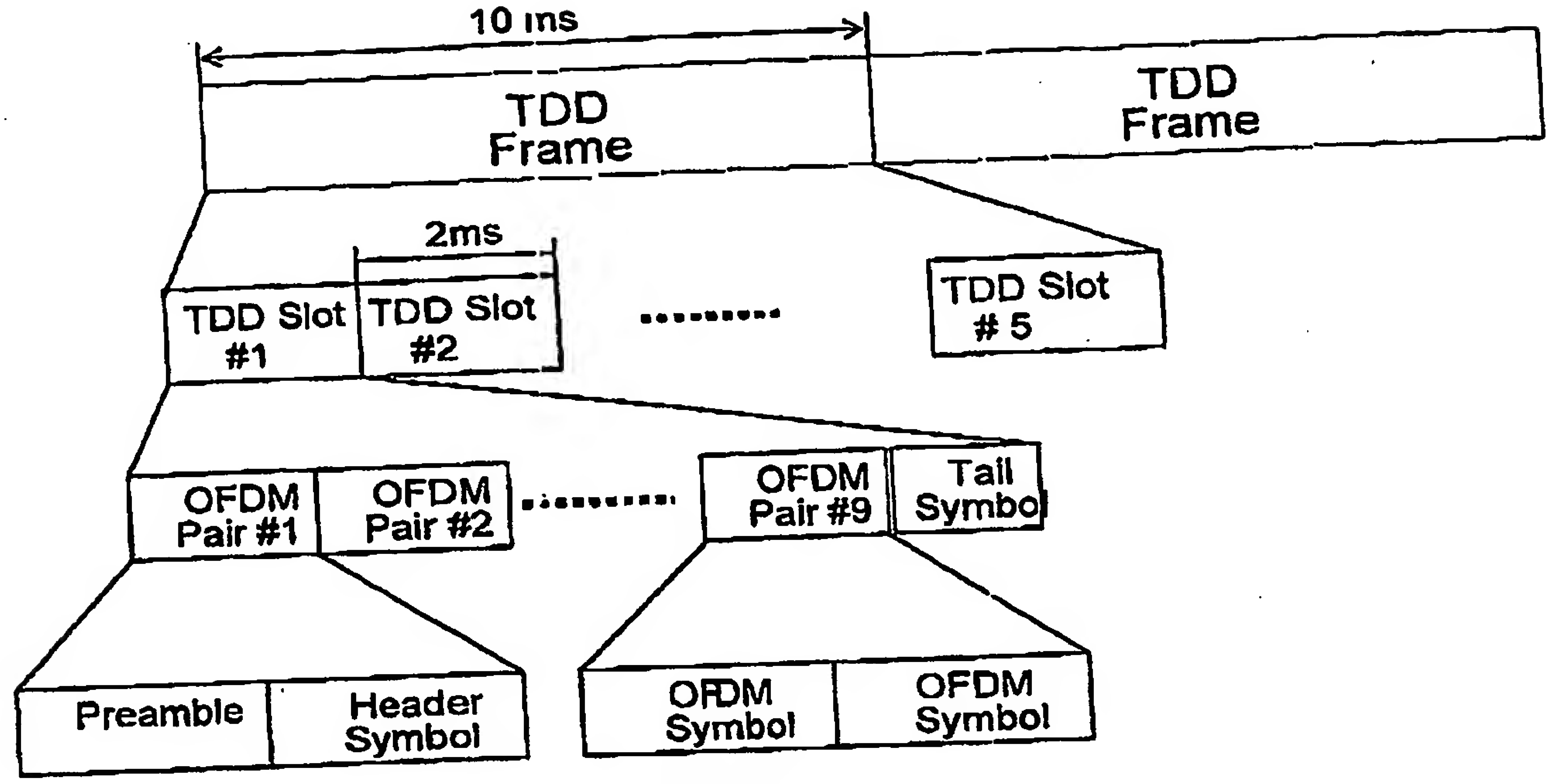

10 ms
TDD Frame
TDD Frame
2ms
TDD Slot #1
TDD Slot #2
TDD Slot # 5
OFDM Pair #1
OFDM Pair #2
OFDM Pair #9
Tail Symbol
Preamble
Header Symbol
OFDM Symbol
OFDM Symbol

FIG. 1

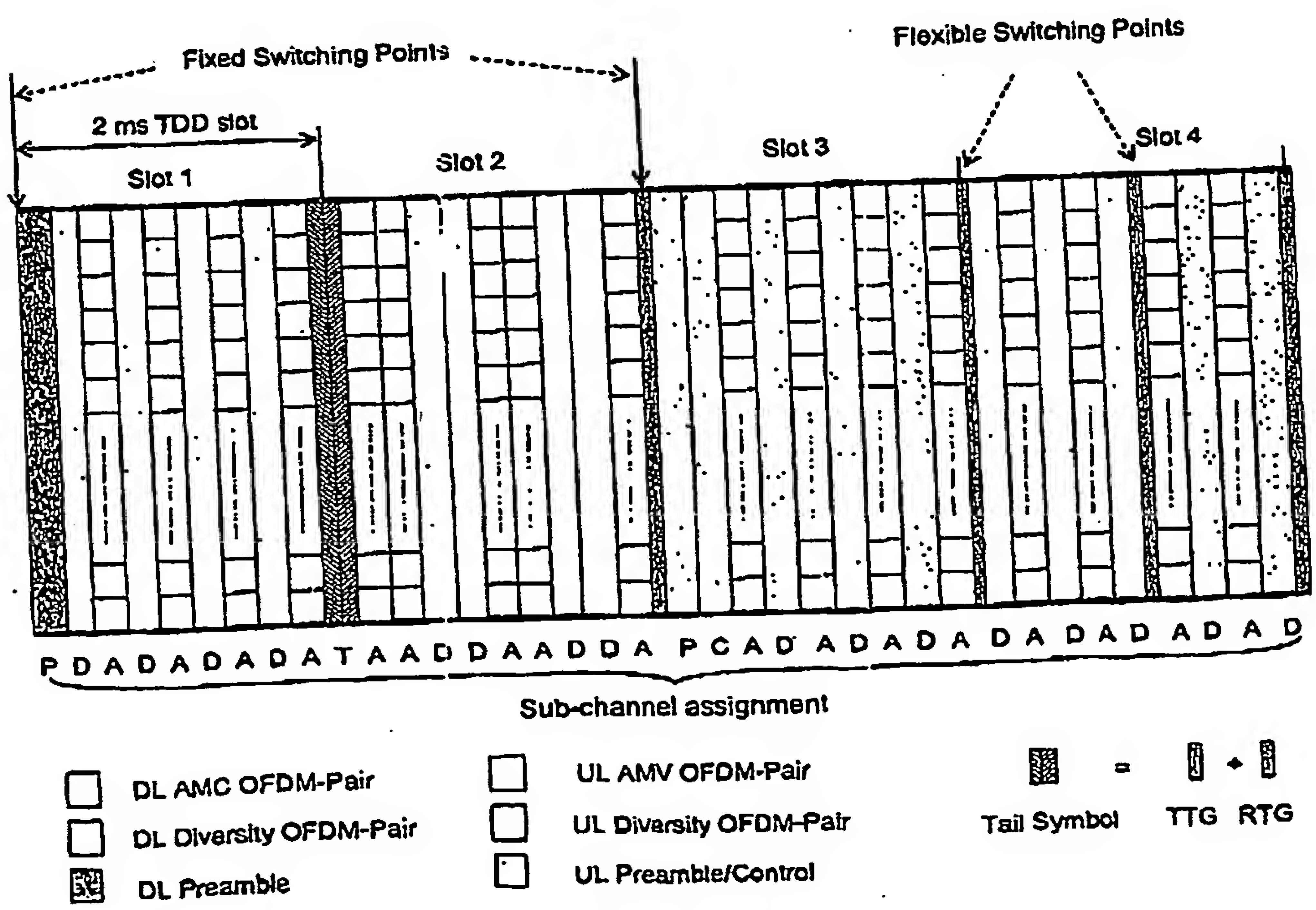

Fixed Switching Points
Flexible Switching Points
2 ms TDD slot
Slot 1
Slot 2
Slot 3
Slot 4
P D A D A D A D A T A A D D A A D D A P C A D A D A D A D A D A D A D A D
Sub-channel assignment
DL AMC OFDM-Pair
DL Diversity OFDM-Pair
DL Preamble
UL AMV OFDM-Pair
UL Diversity OFDM-Pair
UL Preamble/Control
Tail Symbol
TTG
RTG

FIG. 2

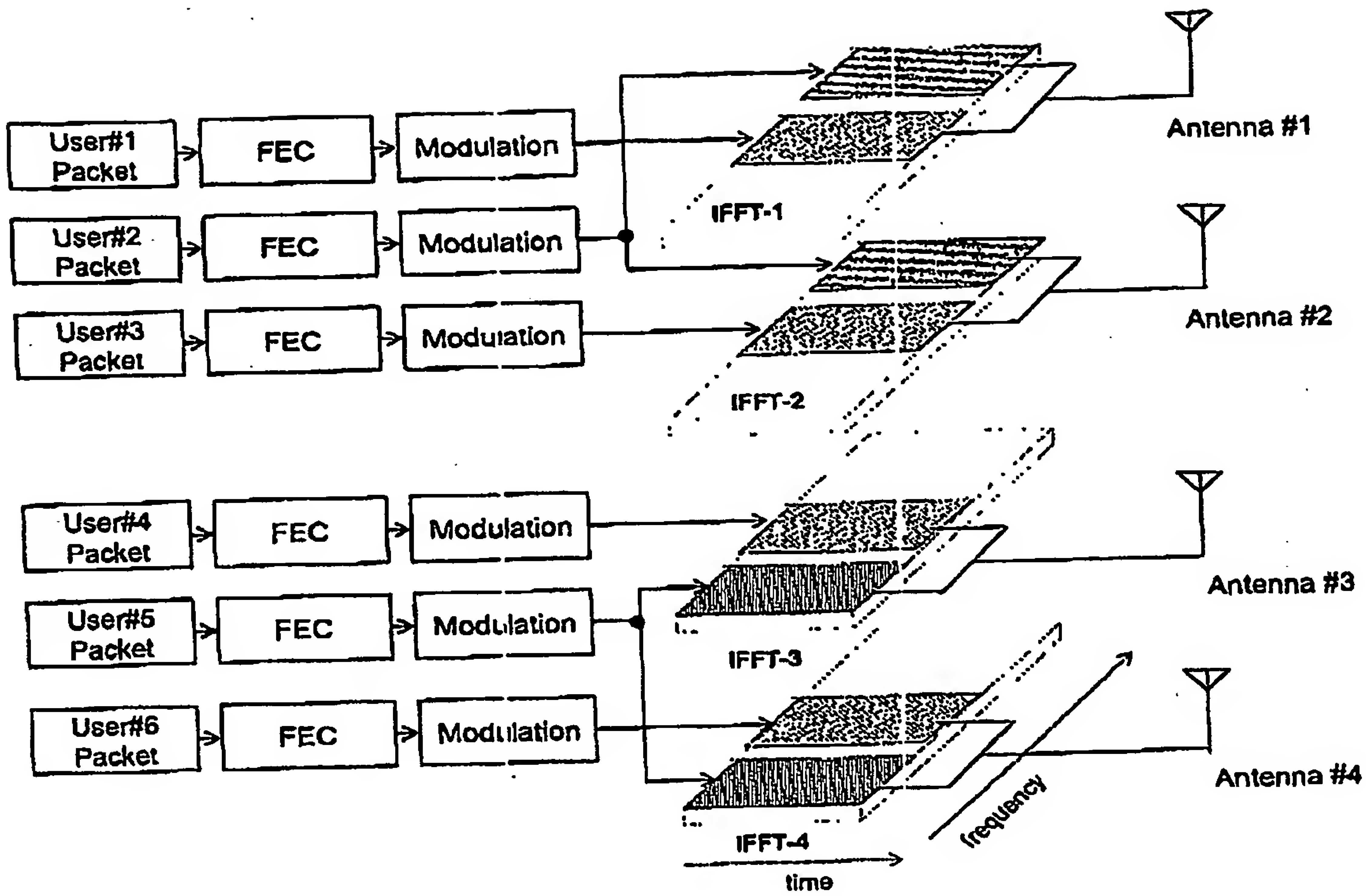

User#1 Packet
FEC
Modulation
User#2 Packet
FEC
Modulation
User#3 Packet
FEC
Modulation
User#4 Packet
FEC
Modulation
User#5 Packet
FEC
Modulation
User#6 Packet
FEC
Modulation
IFFT-1
IFFT-2
IFFT-3
IFFT-4
Antenna #1
Antenna #2
Antenna #3
Antenna #4
time
frequency

FIG. 3

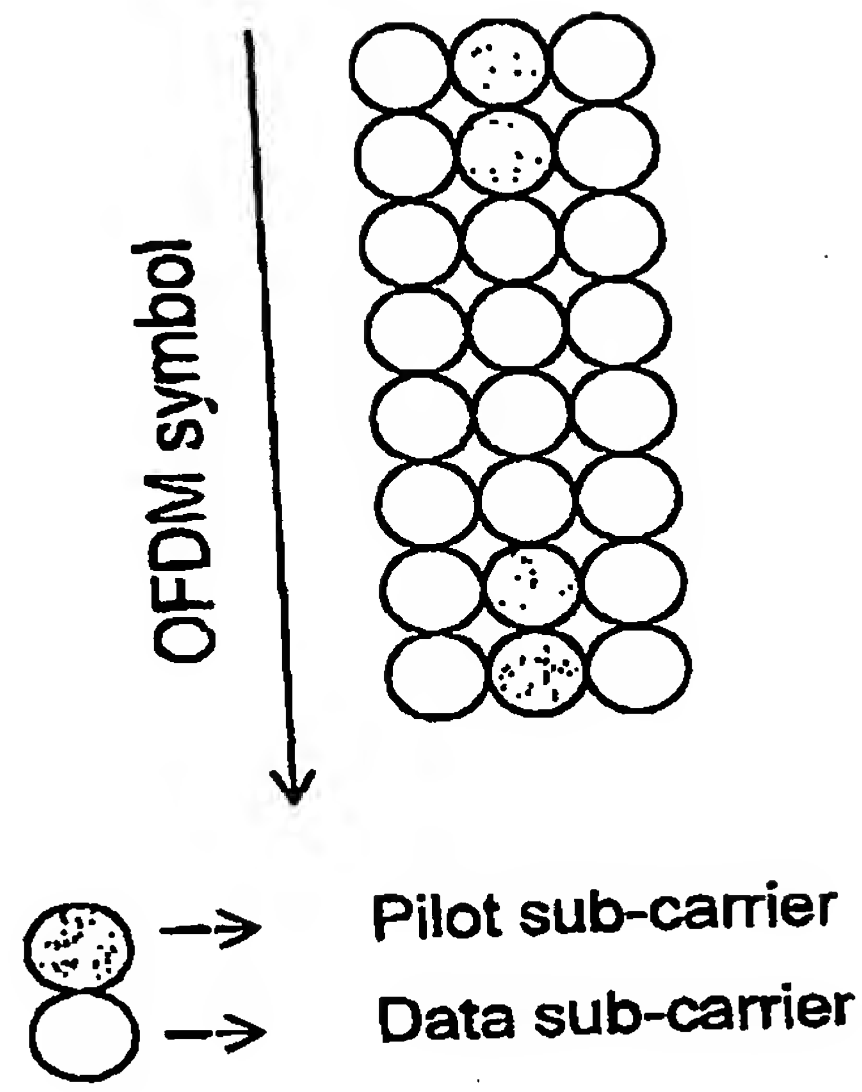


FIG. 4

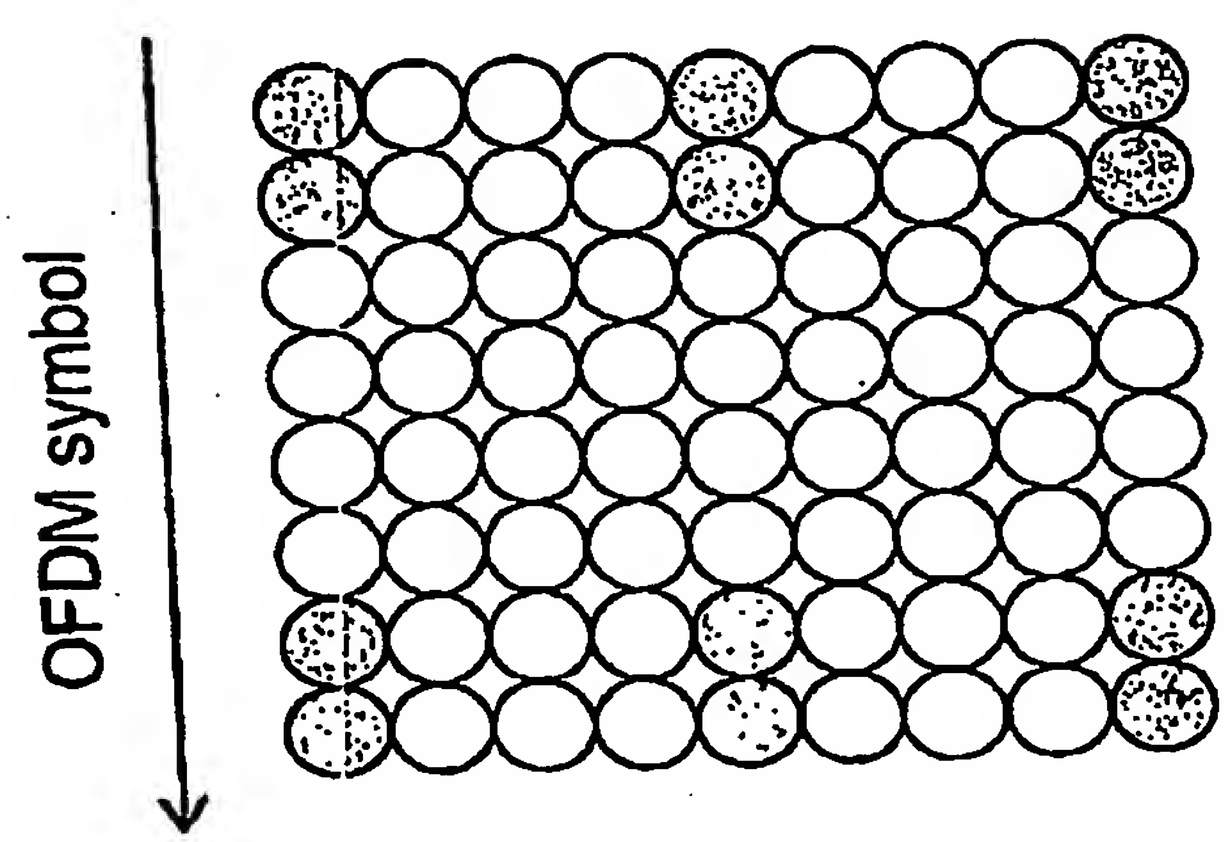


FIG. 5

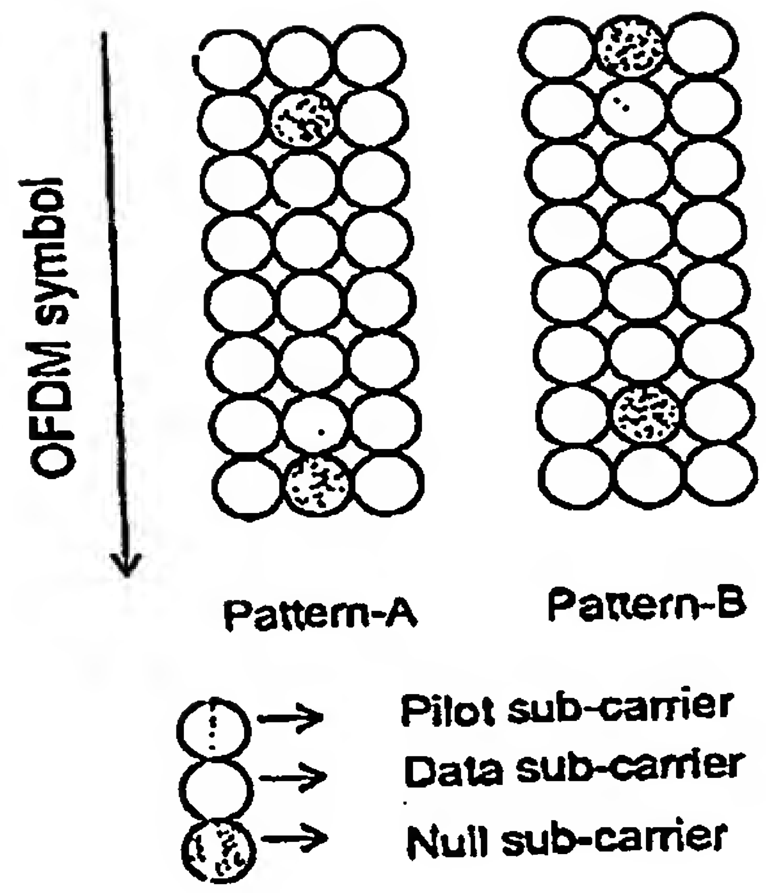


FIG. 6

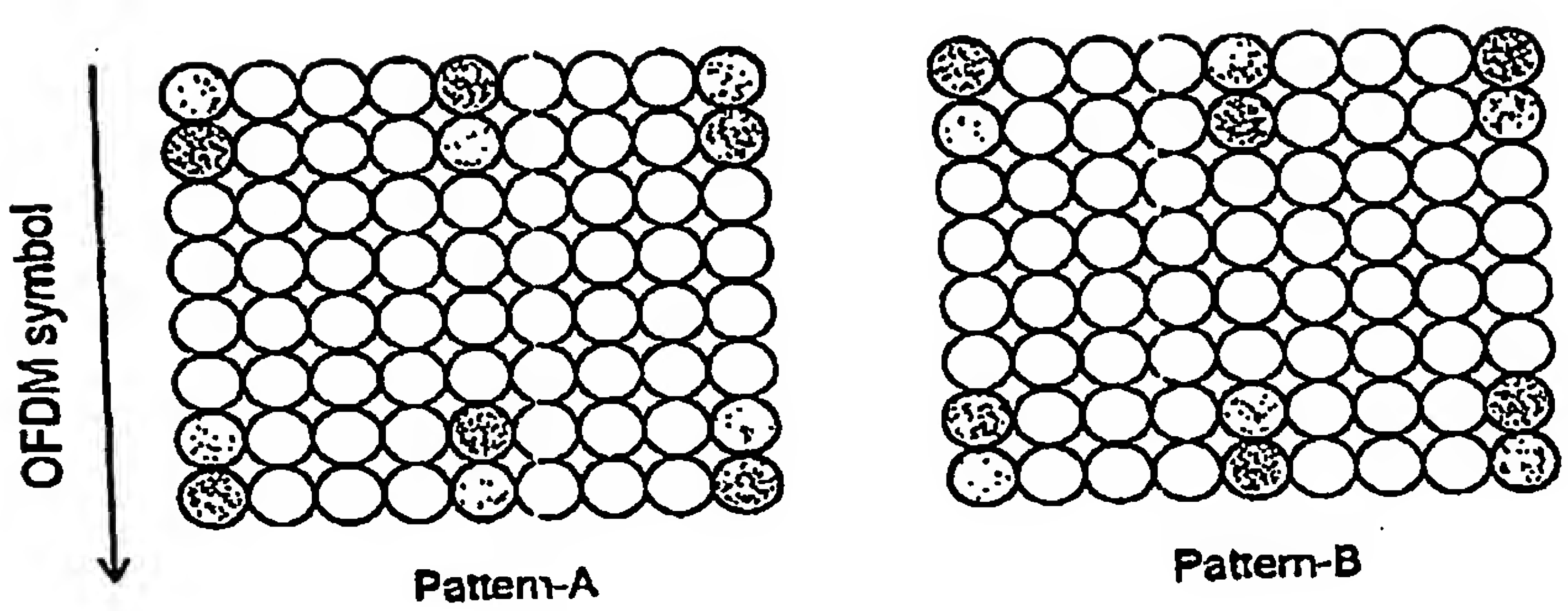


FIG. 7

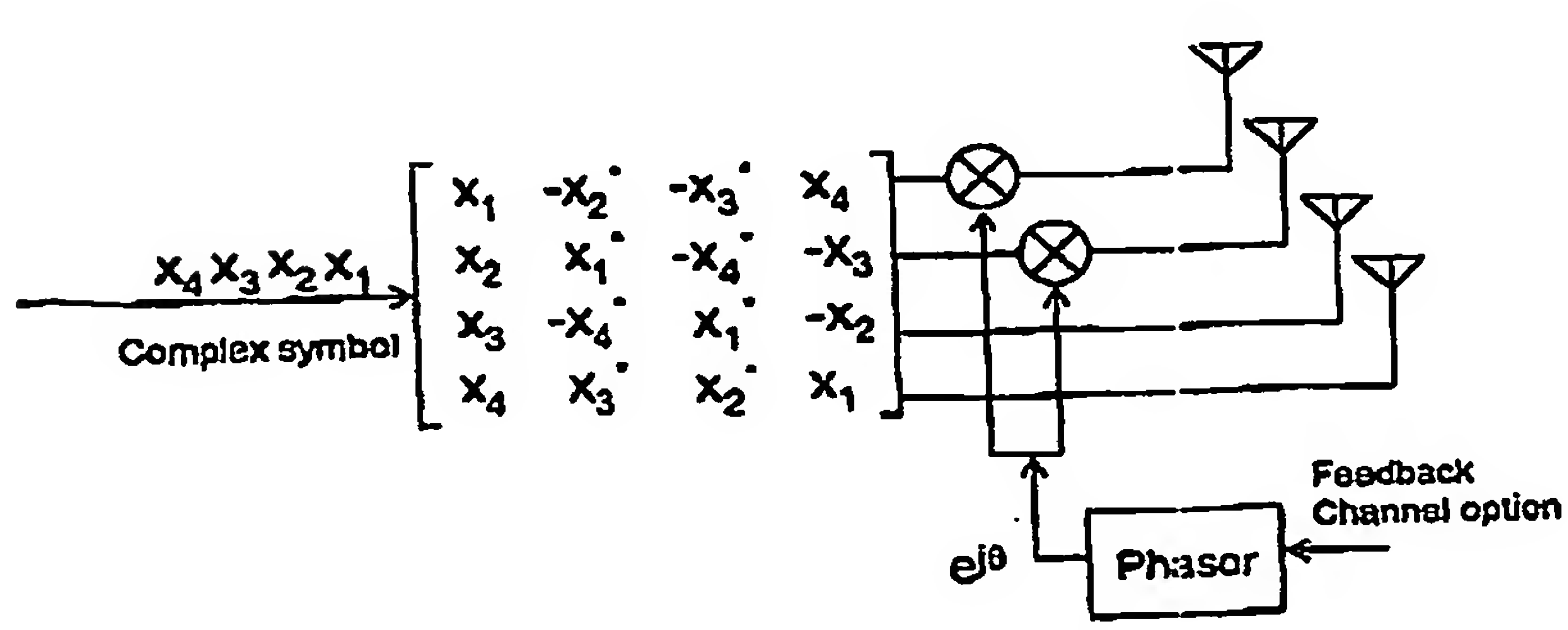


FIG. 8

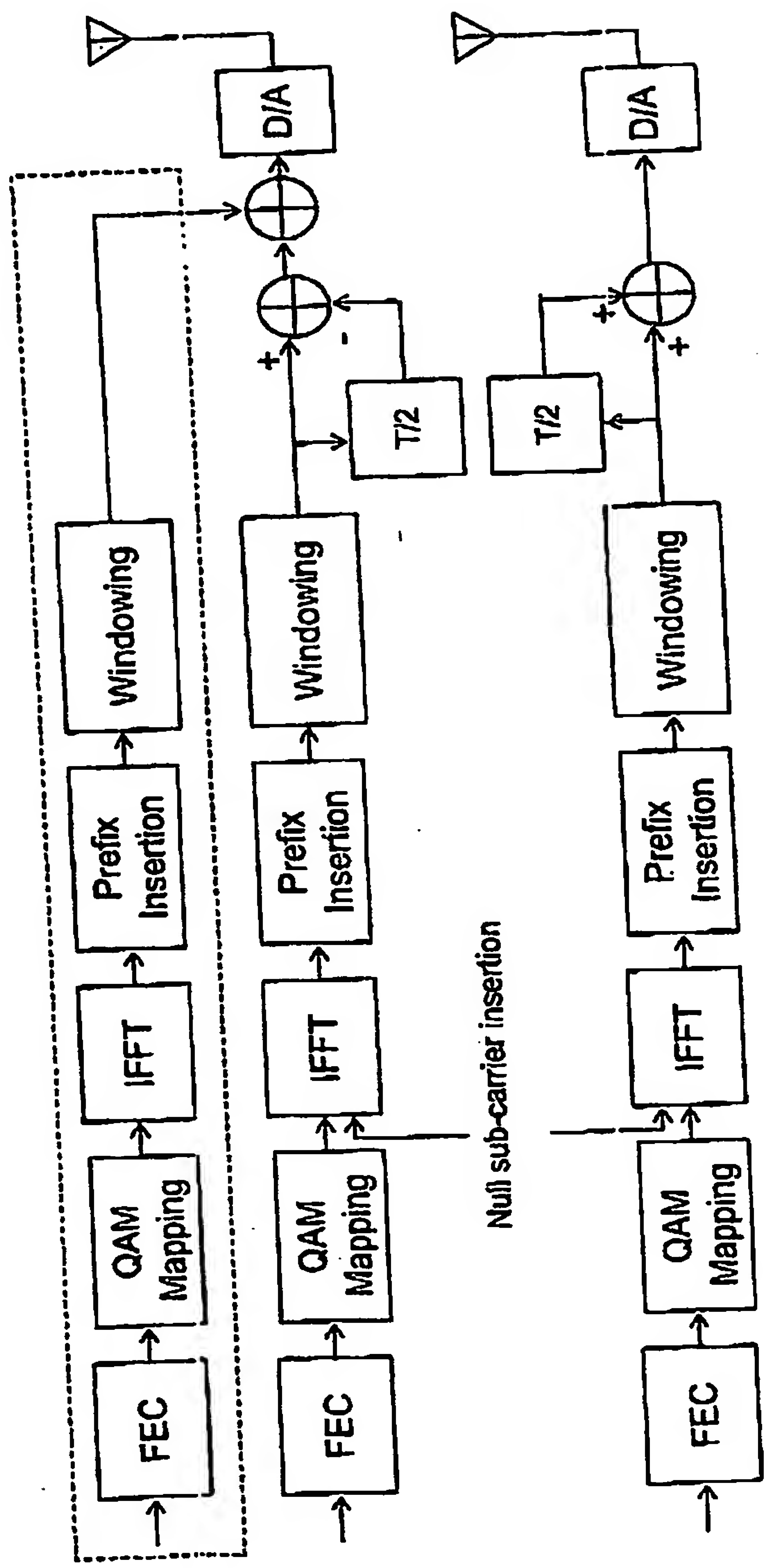

FEC
QAM Mapping
IFFT
Prefix Insertion
Windowing
T/2
D/A
Null sub-carrier insertion

FIG. 9

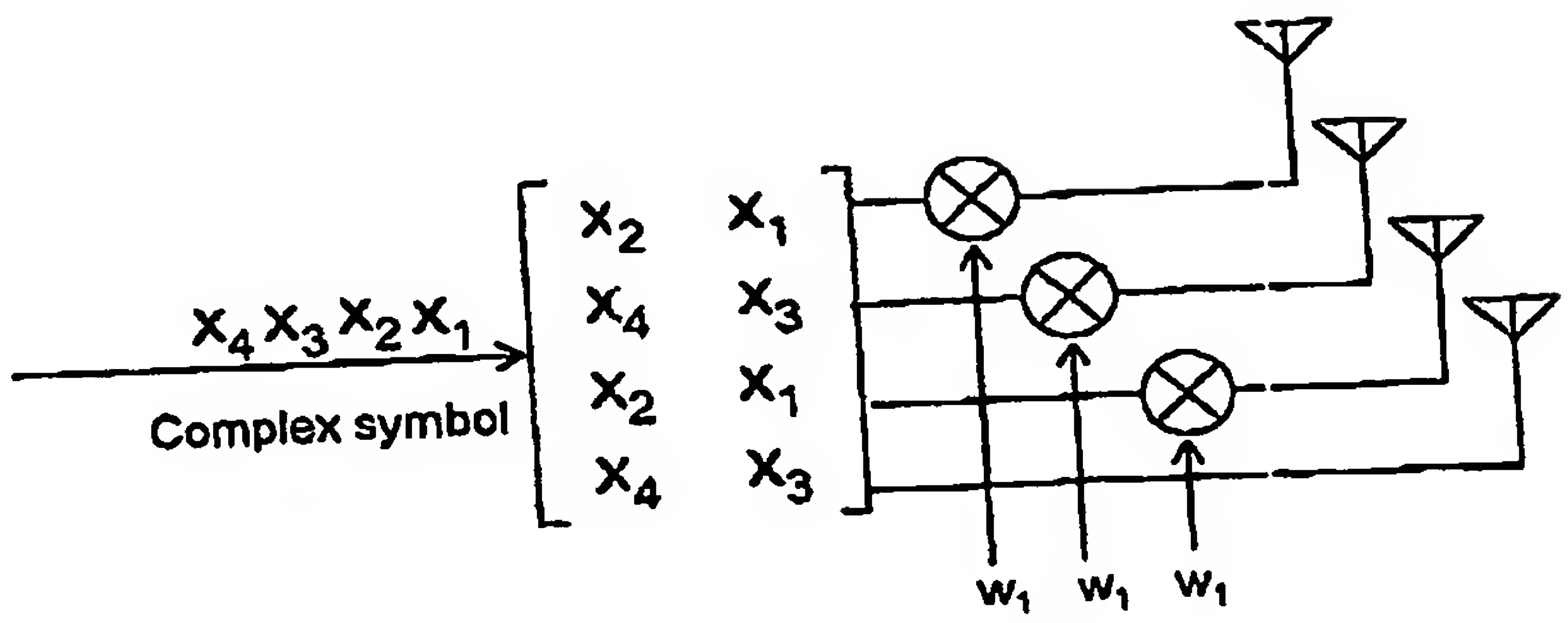

X4 X3 X2 X1
Complex symbol
X2 X1
X4 X3
X2 X1
X4 X3
W1 W1 W1

FIG. 10

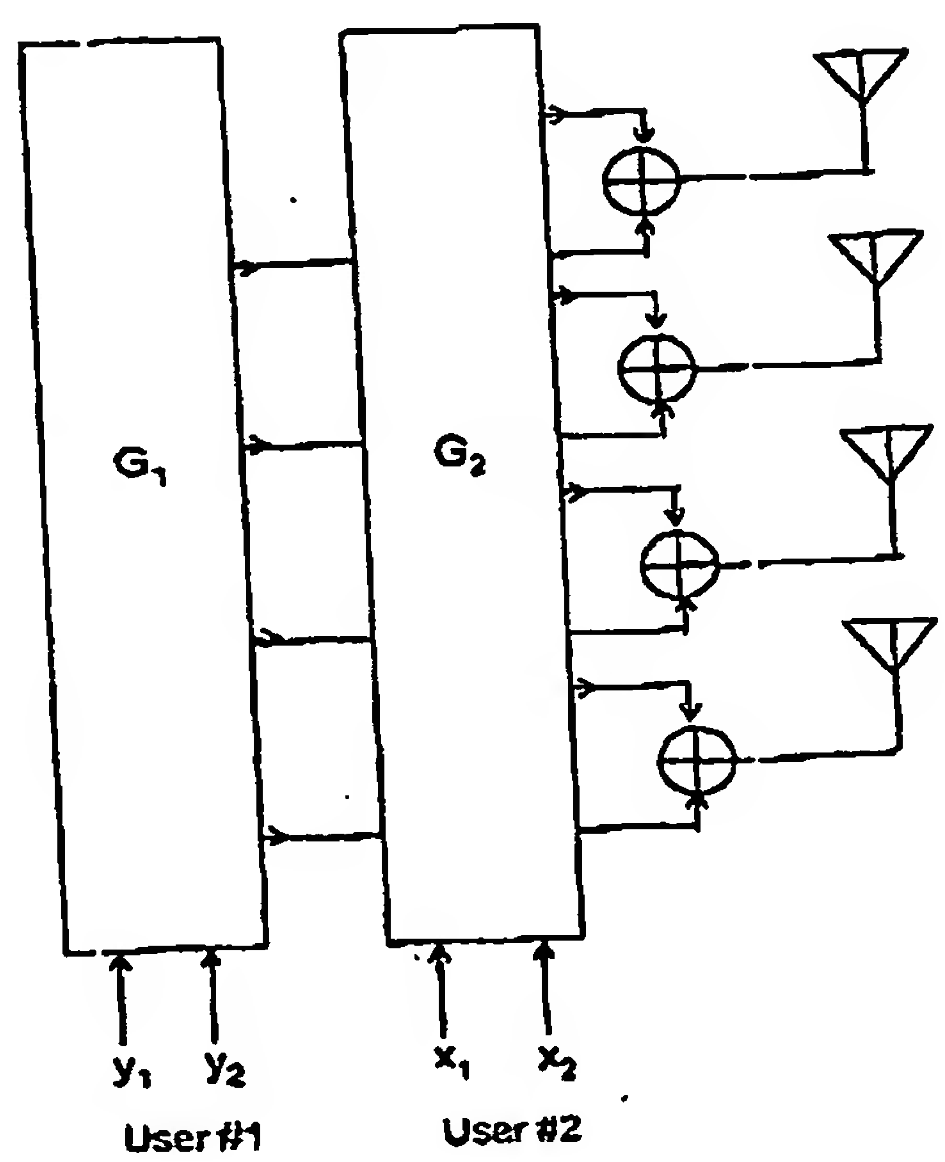

G1
G2
y1 y2
User #1
x1 x2
User #2

FIG. 11

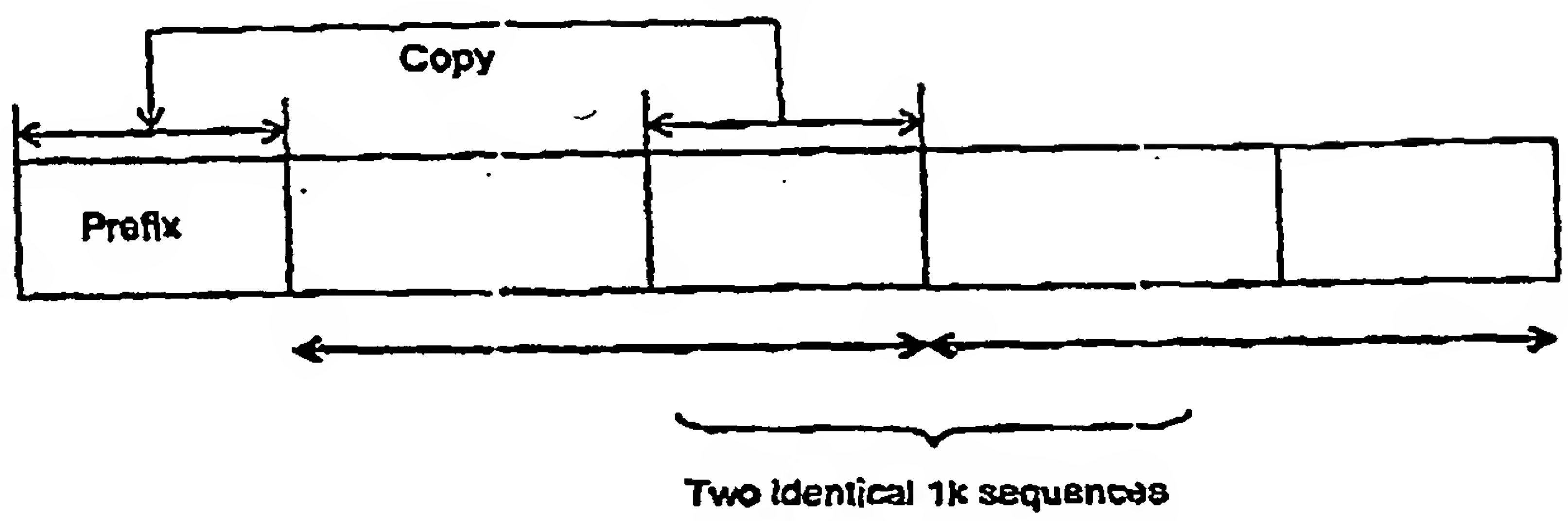


FIG. 12

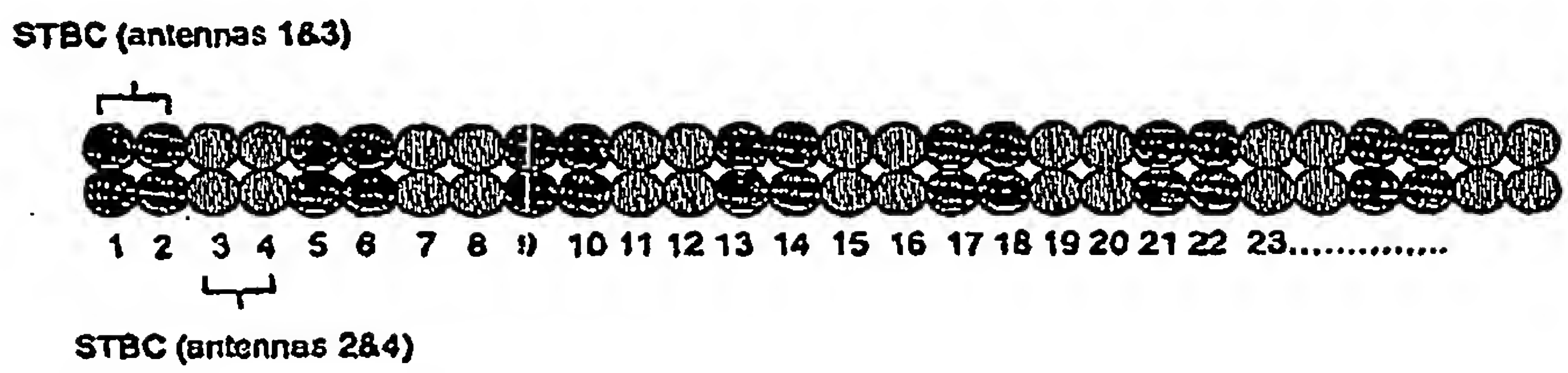


FIG. 13

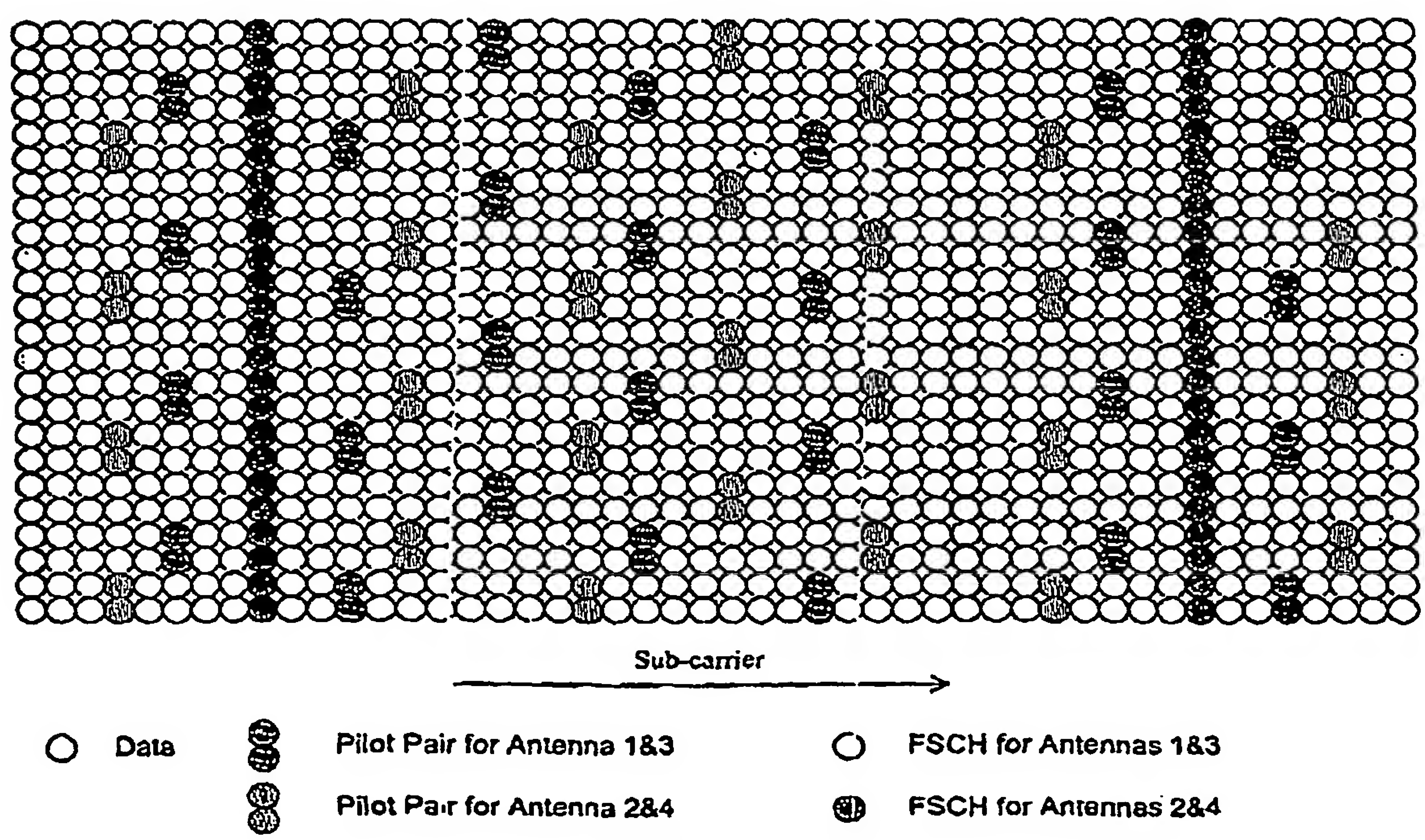


FIG. 14

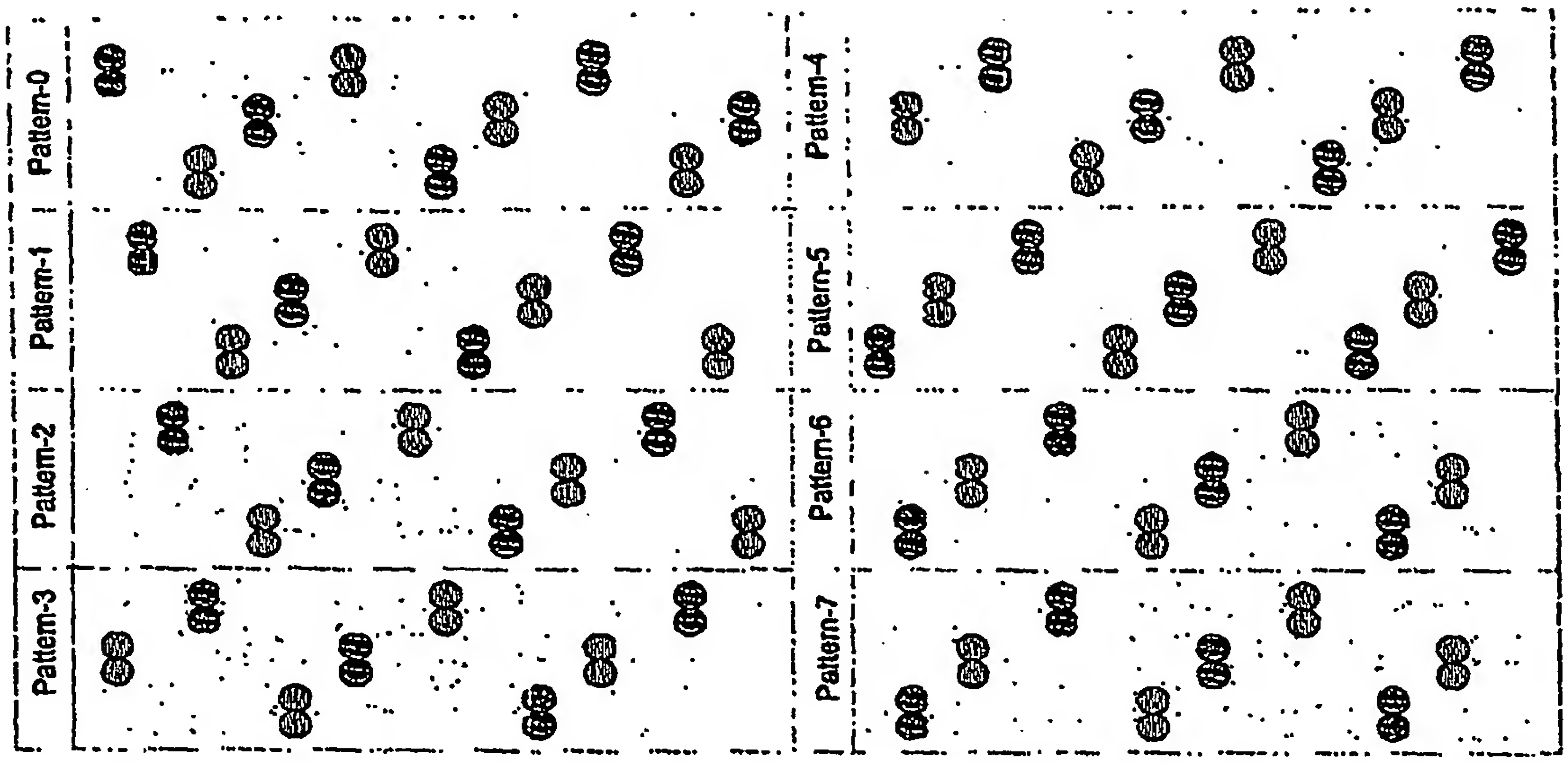

Pattern-0
Pattern-1
Pattern-2
Pattern-3
Pattern-4
Pattern-5
Pattern-6
Pattern-7

FIG. 15

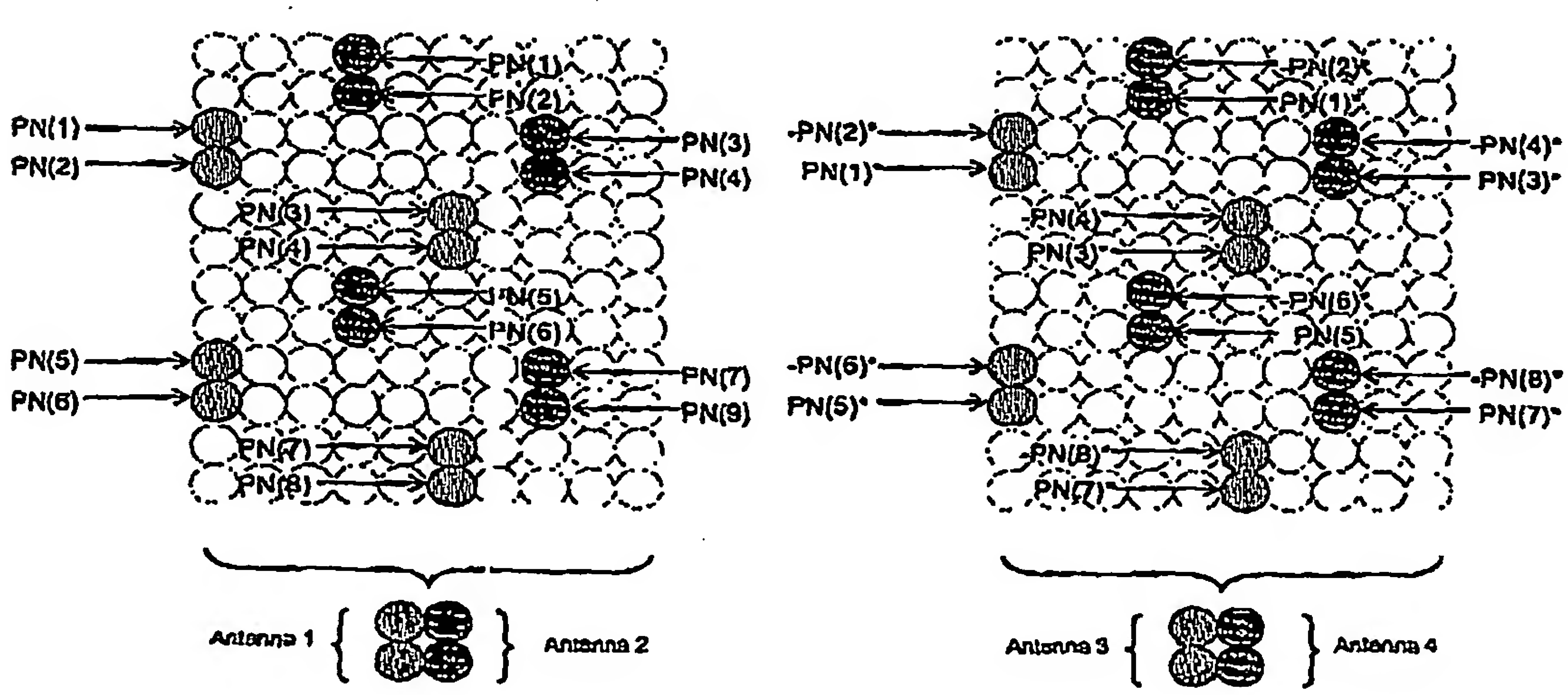

PN(1)
PN(2)
PN(3)
PN(4)
PN(5)
PN(6)
PN(7)
PN(8)
PN(9)
PN(1)*
PN(2)*
PN(3)*
PN(4)*
PN(5)*
PN(6)*
PN(7)*
PN(8)*
Antenna 1
Antenna 2
Antenna 3
Antenna 4

FIG. 16

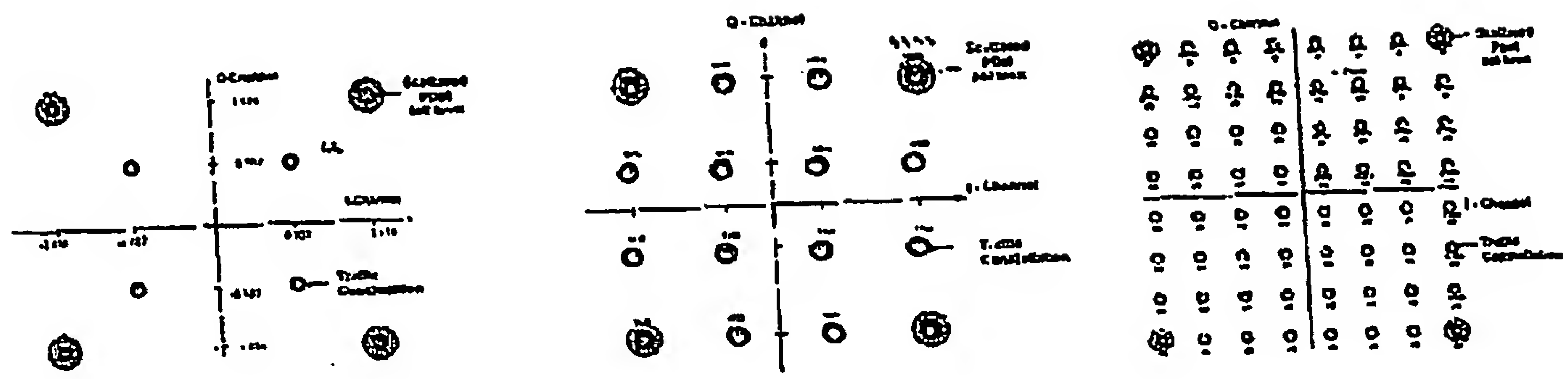


FIG. 17

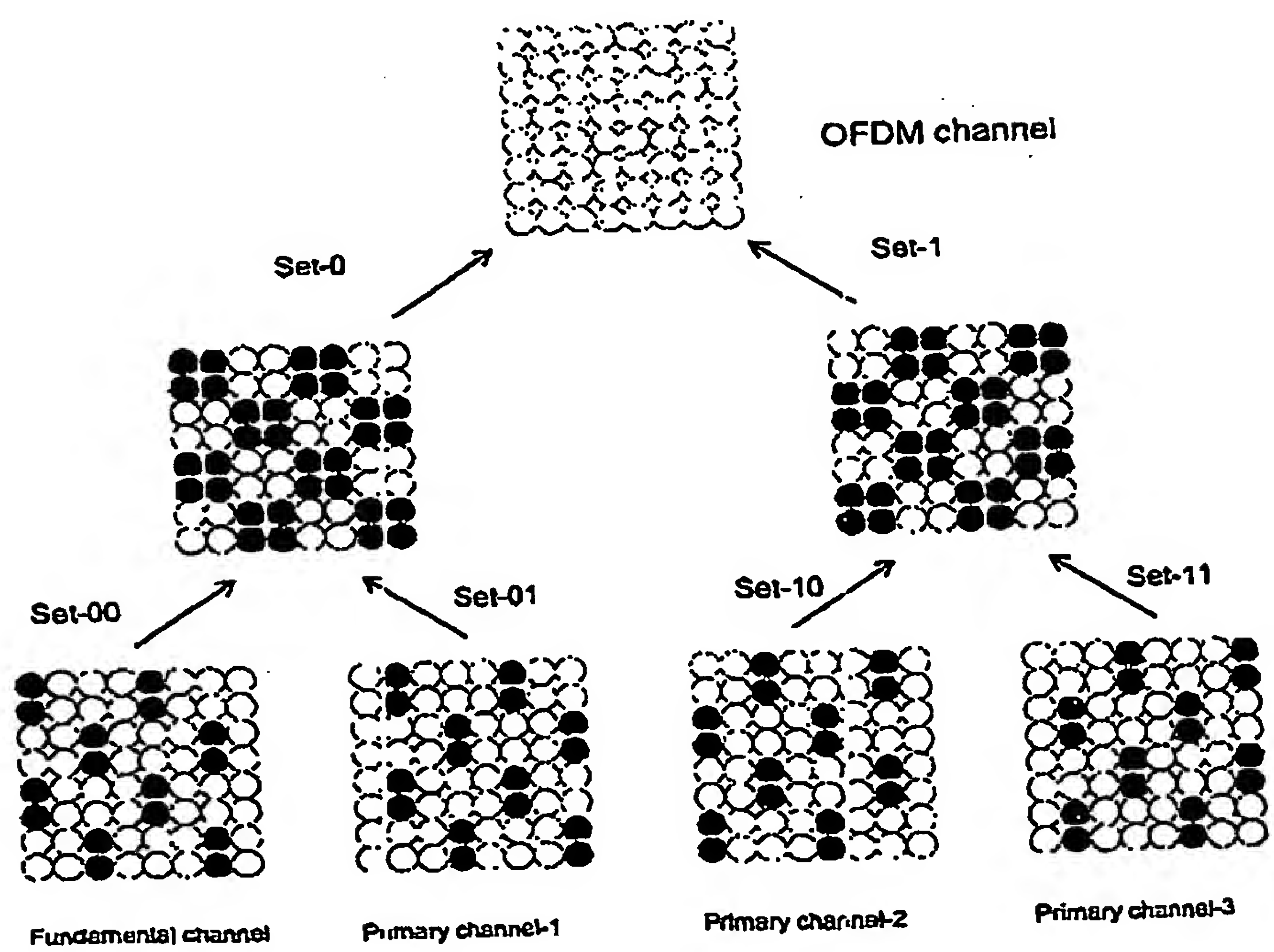

OFDM channel
Set-0
Set-1
Set-00
Set-01
Set-10
Set-11
Fundamental channel
Primary channel-1
Primary channel-2
Primary channel-3

FIG. 18

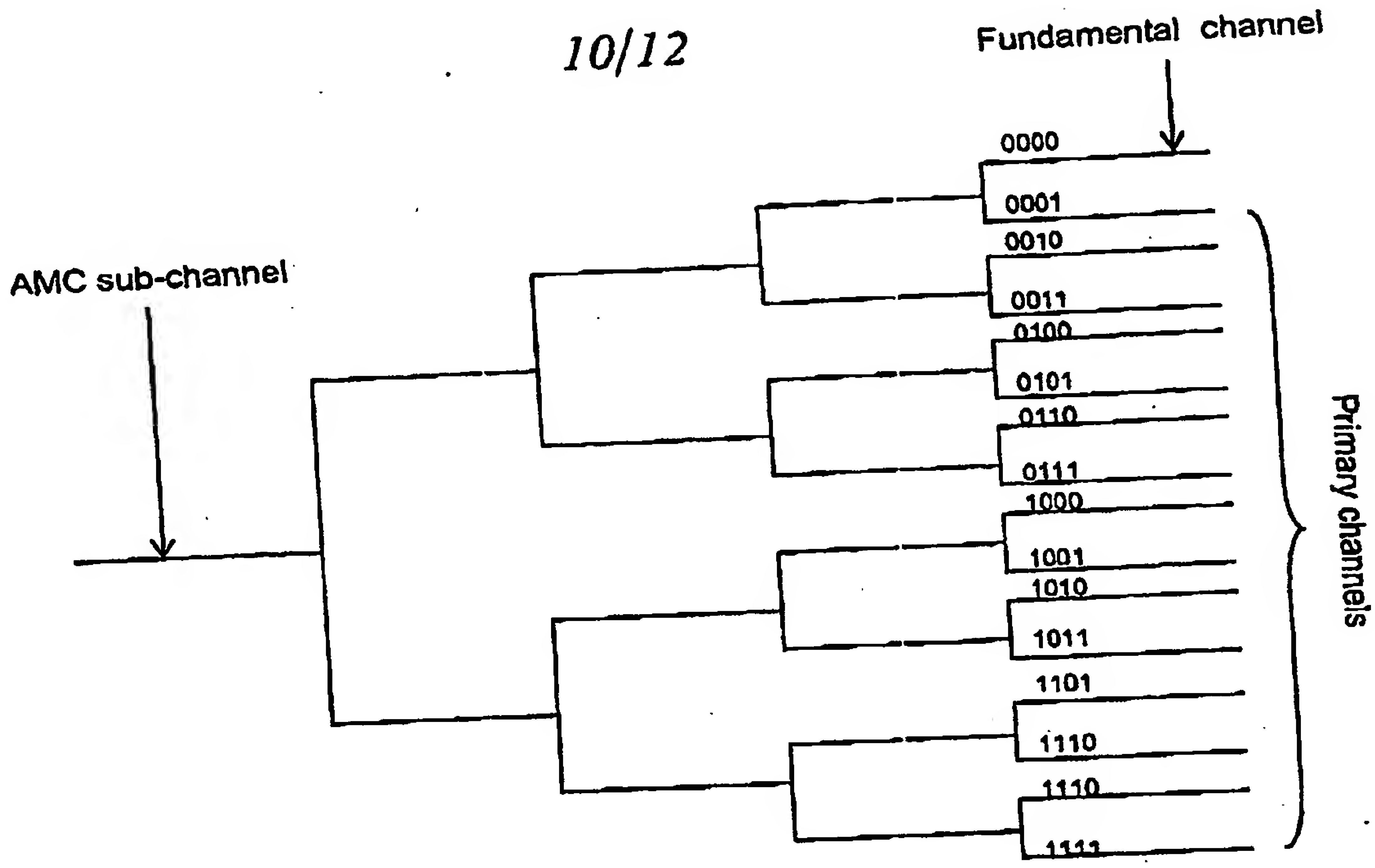

Fundamental channel
AMC sub-channel
0000
0001
0010
0011
0100
0101
0110
0111
1000
1001
1010
1011
1101
1110
1110
1111
Primary channels

FIG. 19

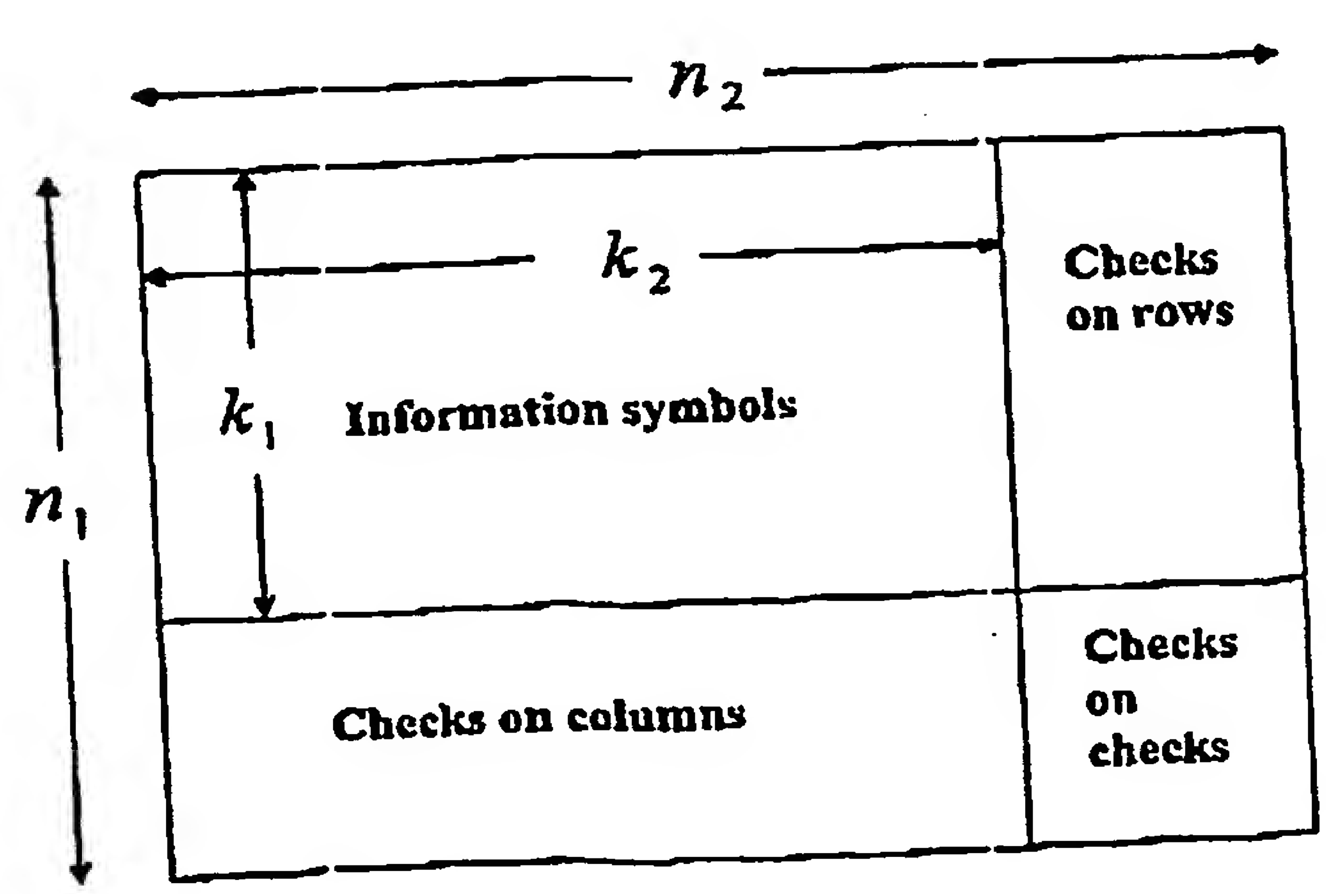

n_2
k_2
k_1
n_1
Information symbols
Checks on rows
Checks on columns
Checks on checks

FIG. 20

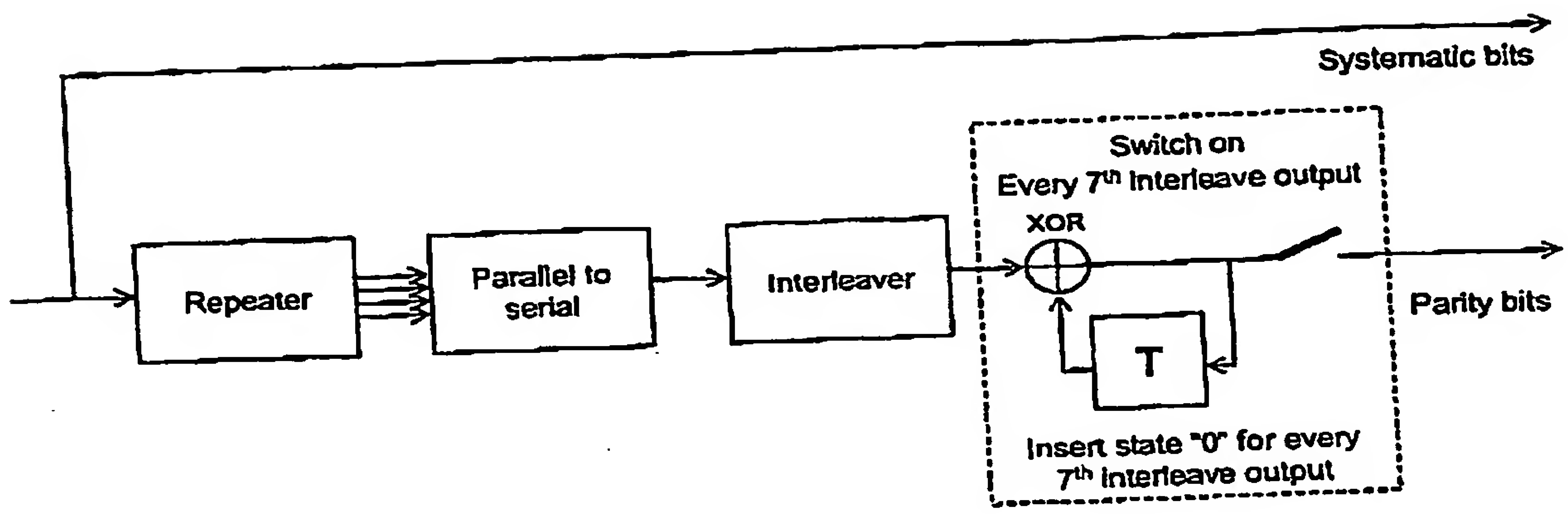

Systematic bits
Switch on
Every 7th interleave output
XOR
Repeater
Parallel to serial
Interleaver
Parity bits
T
Insert state "0" for every 7th interleave output

FIG. 21

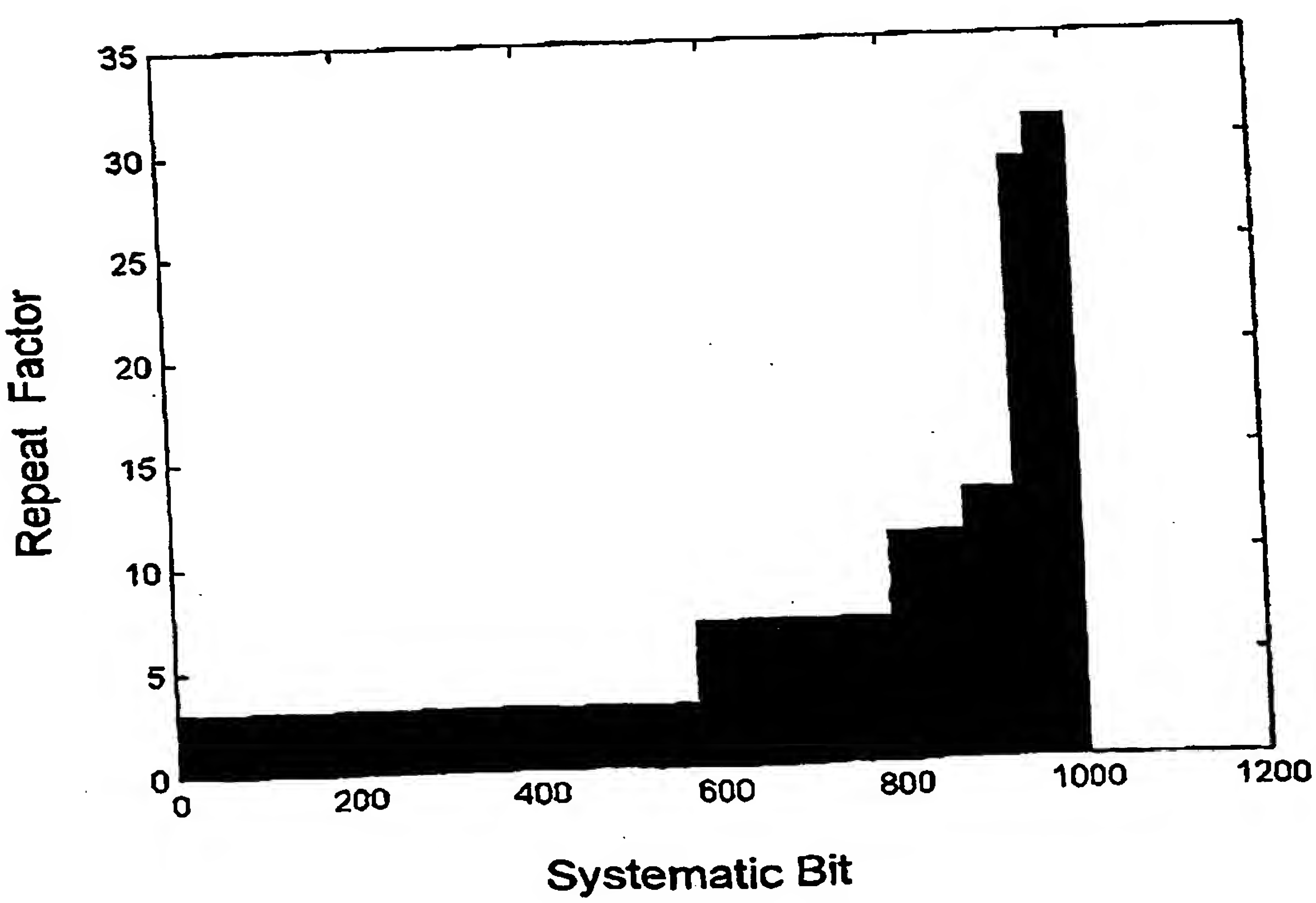
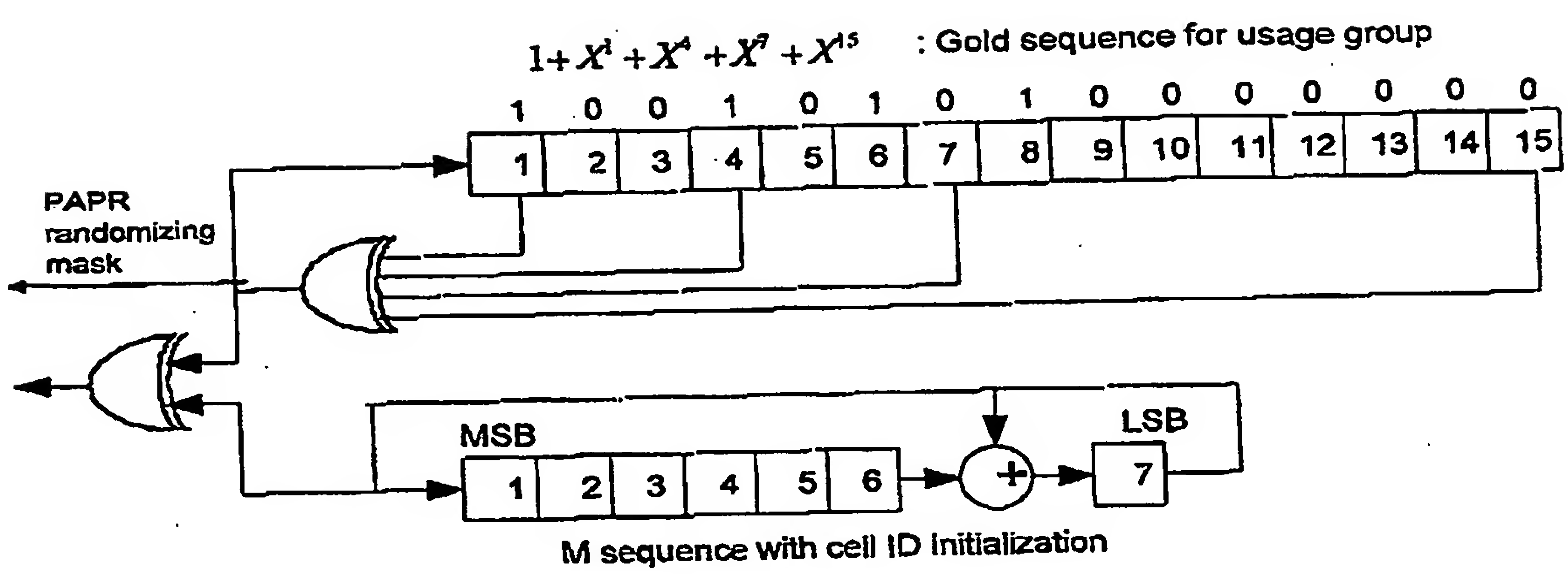

35
30
25
20
15
10
5
0
Repeat Factor
0
200
400
600
800
1000
1200
Systematic Bit

FIG. 22



$1+X^1+X^4+X^7+X^{15}$: Gold sequence for usage group
1 0 0 1 0 1 0 1 0 0 0 0 0 0 0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
PAPR randomizing mask
MSB
LSB
1 2 3 4 5 6
7
M sequence with cell ID Initialization

FIG. 23